FERTILIZER REQUIREMENTS OF SWEET CORN

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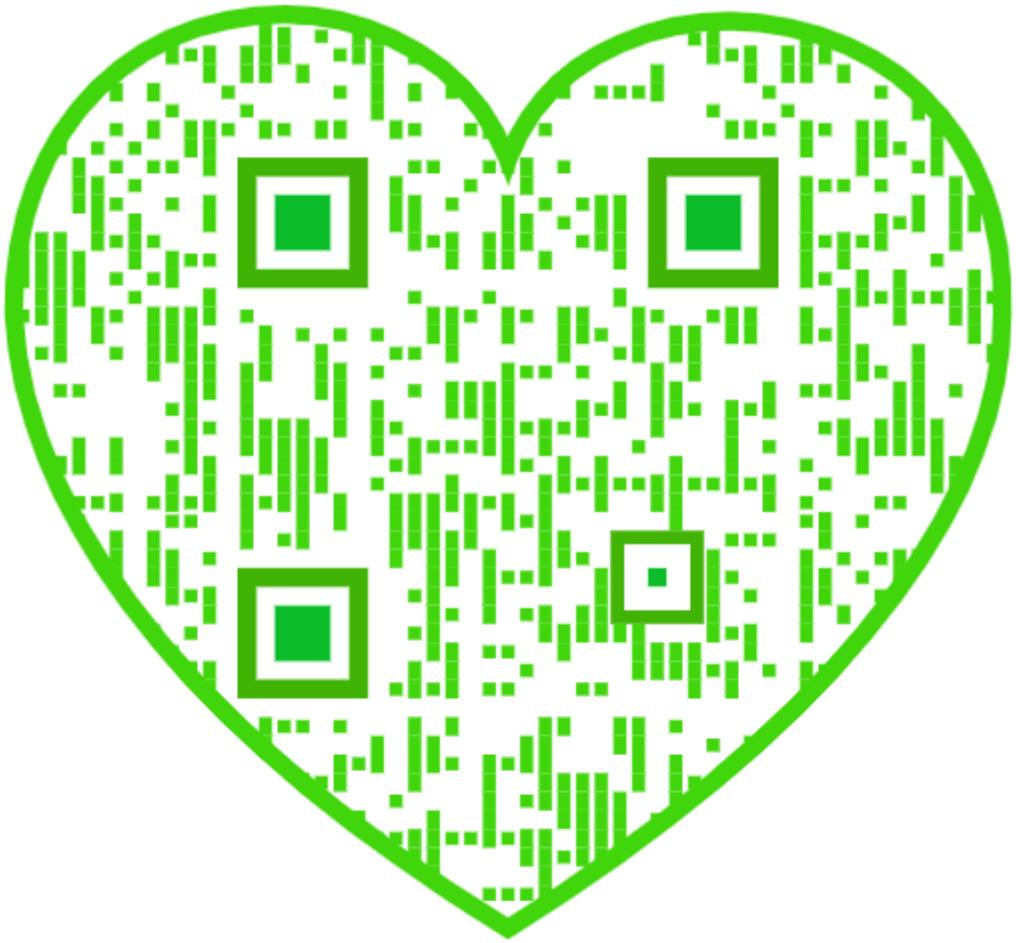

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Urbana, Illinois July, 1935

Publications in the Bulletin series report the results of investigations made by or sponsored by the Experiment Station.

Fertilizer Requirements of Sweet Corn

By W. A. Huelsen, Associate Chief in Olericulture, and
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SWEET CORN is the most important truck and canning crop grown in Illinois, and Illinois is the leading state in acreage and total production of this crop. Notwithstanding this prominence of sweet corn as a vegetable crop, comparatively little published information is available concerning the many problems encountered every season in growing it. There is a particular dearth of reliable information in regard to the effectiveness of commercial fertilizers when used with sweet corn.

Sweet corn is grown on a commercial scale in Illinois chiefly in certain parts of the central and northern sections of the state, where soil conditions are exceptionally favorable. Canners make a practice of contracting with only the most capable farmers who have good land and who rotate their crops with legumes. In spite of such careful choice of growers, sweet-corn yields are not as high as they should be, as is evident upon calculating the theoretical total yield that could be obtained from an acre on the basis of a single ear to the plant. The normal ear in late-maturing varieties weighs about 12 ounces unhusked. Multiplication of this weight by the normal number of plants per acre, which varies from 9,000 to 12,000, indicates that production should be from 6,750 to 9,000 pounds an acre. Even the smaller yield, however, is rather exceptional, tho yields as high as seven tons to the acre are occasionally recorded from limited acreages.

Sweet-corn growers are familiar with calculations such as these and have made numerous attempts to increase their yields. The most obvious step has been to apply commercial fertilizers, but except in isolated instances their use has been abandoned because of very slight or even negative responses. Bushnell,[13*] who studied the effects of fertilizers on tomatoes, cabbage, cucumbers, and sweet corn, found that altho sweet corn responded better to potash than did cabbage, it gave the least response to nitrogen and phosphorus of any of the four crops. Lloyd[35*] found that manure increased yields of sweet corn, but that phosphorus gave favorable results only in certain com-

[a]Acknowledgment is made to the following former members of the staff and graduate assistants for their help at various times in carrying on the work of this project: E. P. Lewis, H. F. Jenkins, R. W. Axt, L. A. Koritz, and C. P. Wilsie.

*These numbers refer to literature citations, pages 427 to 429.

binations, that nitrogen reduced the yields, and that potash failed to give any appreciable result.

It would be quite misleading to assume that this lack of favorable response by sweet corn to certain commercial fertilizers is due to a low requirement of plant food. As a matter of fact, according to Whiting,[55]* sweet corn requires comparatively large amounts of plant food. Evidently the sweet-corn plant is rather critical in its requirements, and the selection of appropriate fertilizer ratios is not a simple matter, but one requiring intricate experiments carefully planned and accurately controlled.

PURPOSE OF EXPERIMENTS

The specific purpose of this work was to study the effects on yield and maturity of sweet corn of a large number of fertilizer combinations applied to a dark silt loam prairie soil typical of the soils on which sweet corn is grown in Illinois, the sweet corn being included in a four-year rotation commonly used thruout the state. Other problems, such as methods of application, were postponed for later consideration.* In all, the experiments covered ten growing seasons (1923-1932), but only the fertilizer-ratio studies covering the period from 1923 to 1928 are reported here. Subsequent studies covering certain supplementary problems are being prepared for later publication.

PLAN AND SCOPE OF EXPERIMENTS

In order to carry out the purpose of these studies—namely, to determine the most effective fertilizer combinations for the commercial production of sweet corn under Illinois conditions—the type of soil on which the tests were made and the rotation and field methods used were as representative as possible of the commercial growing of sweet corn. Four fields near Urbana were selected that were large enough to supply one plot and a check plot for each fertilizer combination used in the experiments. The identity of plots and treatments was maintained thruout the six years covered by the fertilizer-ratio studies.

The Experimental Fields

Soil Type.—The experiment was laid out at Urbana on an upland prairie soil that includes several soil series common to the region.

*A few statements and recommendations in regard to methods of application are made in the present bulletin. They are based on subsequent experimental work not reported here.

Three of the fields (Nos. 800, 900, and 1000) appeared to be practically similar, but the fourth (Field 1300) was located partly on the Champaign moraine system and consisted mostly of a gravelly loam in a low state of fertility.

Topography and Drainage.—Fields 800, 900, and 1000 were slightly rolling and subject to sheet erosion. Field 1300 was quite rolling. In each field the plots were laid out in such a manner that the surface water flowed across them rather than lengthwise of them. Wide alleys gave an opportunity for diverting surface drainage in such a way as to reduce the damage to a minimum.

Subsoil drainage in Fields 800 and 1000 was satisfactory, but in the others (Fields 900 and 1300) water collected in two small areas for twenty-four hours or more after heavy rains. The plots thus affected were abandoned for experimental purposes.

Soil Acidity.—Suitable tests in each field indicated a lime requirement of two to three tons an acre. This deficiency was remedied by broadcasting the required amounts of limestone on each field.

Previous History of Plots.—Field 800 had been used for grain farming for an indefinite period. It was planted to wheat in 1918, 1919, and 1920, and in 1921 it was planted to field corn and manured in the fall.

Field 900, located 80 rods north of Field 800, had also been used for grain farming. In 1918 it was planted to field corn, in 1919 to oats, in 1920 and 1921 to field corn. A small part of the north end had been planted to oats in 1921. At least two coats of manure had been applied between 1918 and 1921.

Field 1000, located on a near-by farm, had been planted to a timothy-bluegrass pasture in 1919, 1920, 1921, and 1922.

Field 1300 was located 40 rods east of Field 1000. It had been planted for an indefinite period to corn and oats.

None of the fields had ever received an application of limestone or commercial fertilizer.

How Experiments Were Conducted

Rotation.—A four-year rotation consisting of wheat or oats, red clover, and two sweet-corn crops was used in connection with these experiments. In years when small grain was grown in a given field, the grain was planted over the entire field, including alleys, as uniformly as possible. Medium red clover was seeded at the proper time at the rate of 12 pounds an acre. The grain crop was cut in the usual manner and all straw, except the stubble, removed. In the following

spring the first crop of clover was cut as hay and removed; the second crop was plowed under in September or October.

In subsequent tables, data are given separately for Field 800 in 1923 and Field 1300 in 1924 and 1925 under the heading "No clover in rotation." These fields were plotted, fertilized, and planted to sweet corn at the beginning of the experiment before any clover had been used. They therefore come under the separate heading mentioned above.

Strictly speaking, Field 1000, which is placed under "First year after clover" in 1923 and "Second year after clover" in 1924, also should have been under "No clover in rotation," but as this field had been in livestock pasture for four years, it was thought best to consider the sod as equivalent to clover.

Field Methods.—The ground was fall-plowed by tractors in accordance with the usual practice in Illinois. Spring preparation for the corn crop consisted of double-disking twice, after which the plots were laid out and the fertilizer broadcast by hand on the plots but not in the alleys between them. The fertilizer was always harrowed in at once with a spike-tooth harrow. The plots were then marked out very carefully and invariably planted within twenty-four hours. The corn was planted in check rows 42 by 42 inches apart, by means of a hand planter known to farmers as a "jabber," from which the mechanism had been removed. Four to six kernels were dropped by hand into the planter. The stand was thinned two to three weeks later to three plants per hill. Excess seed insured a practically perfect stand, barring such accidental losses as those from gophers or cutworms. The variety used thruout was Country Gentleman bred by the Illinois Agricultural Experiment Station. The crop was cultivated according to the usual Illinois methods.

In experimenting with sweet corn, it is difficult to determine when to harvest each plot, especially since some treatments advance and others retard maturity. Appleman and Eaton,[4*] Culpepper and Magoon,[16*] and Meyers[39*] have shown, however, that maturity can be determined with reasonable accuracy by means of silk counts, a workable method which has been used thruout these experiments. The method consists of examining each plot every day or two beginning soon after tasseling, and of counting daily the silks on all plants in the two center rows of each plot from the time silking is under way until the date when 75 percent of the theoretical possible number of silks appear.[a]

[a]The validity of this method will not be discussed here, as it is discussed in a publication now in preparation by the senior author.

That silk counts do not indicate absolutely the date when the crop is ready for harvest should be understood. They give only a close approximation to the exact date, for under normal weather conditions at Urbana about 21 days are required for the crop to pass from the silking to the canning stage in the period between August 8 and September 8. The final dates of harvest were checked further by means of Appleman's[2, 3*] nail test. This test, familiar to all sweet-corn growers, consists of piercing one or more kernels with the thumb nail. The character of the exudate, according to Appleman, is a fairly reliable indication of its composition and therefore of the stage of maturity.

Methods used in harvesting were as accurate as circumstances permitted. The ears from the border rows around the four sides of each plot were removed first. The plot proper was then snapped, the standing order to the workmen being to "snap everything showing a silk." A large number of useless culls were thus included, but on the other hand, no ears fit for canning were overlooked. The ears were then sorted, counted, and weighed by an experienced crew. The cull ears were returned to their respective plots and scattered.

As soon as the corn was harvested, the stalks in the two center rows of each plot were cut and weighed for the "green fodder weights" mentioned later. These stalks were always returned to their respective plots and scattered. It should be noted that nothing more than good canning ears were removed from each plot.

Plot Arrangement.—The plots in the four fields were identical in size—31.5 by 80.5 feet, or .058213 acre (Figs. 1, 2, 3, and 4). This was the area over which the fertilizer was distributed.

The outer boundaries of the plots coincided with the outside, or border, rows. During harvest, the corn from the border rows was removed first and not included in the calculated yields, as stated above, leaving a net plot 28 by 77 feet, or .04949+ acre, upon which basis the yields were calculated. As a planting distance of 42 by 42 inches was used thruout, the plots contained 10 rows each, 24 hills long; after the border rows were removed, 8 rows, 22 hills long, remained. The ratio between the total width and total length was 1:2.56 and the ratio between the net width and net length was 1:2.75.

The distance between the outer boundaries of adjacent plots in each field was 8 feet. The distance between the outer boundaries of abutting plots was 8 feet in Field 1300 and 7 feet in the other fields.

The plots were laid out each year by means of a transit, a bench mark having been established at the beginning of the project. The possible error by these methods was less than ± 1 inch.

In order that every plot receiving fertilizer treatment would be adjacent to a check plot, every third plot in each field was designed as a check. Conditions on adjacent plots were made as nearly identical as possible, with the single exception that no check plot was given fertilizer treatment.

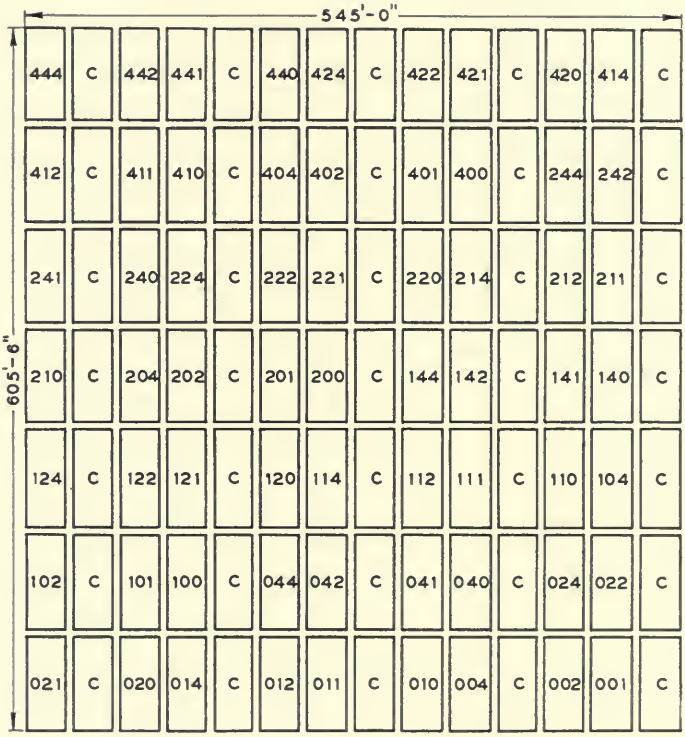

FIG. 1.—PLOT ARRANGEMENT IN FIELD 800

The fertilizer treatments applied to the plots are indicated by code numbers (see pages 364-5). Check plots are designated by "C." The arrangement of treated plots and check plots charted here, and the treatment indicated for each plot, were retained without change thru the six years covered by these fertilizer experiments. (This explanation of the fertilizer layout for Fig. 1 applies also to Figs. 2, 3, and 4.)

Fertilizers Used.—The fertilizers used in varying dosages and varying combinations were the following: (1) *Nitrate of soda,* used for nitrogen thruout the experiment, was applied separately as a side dressing around the hills three to six weeks after planting, and then covered with a corn cultivator. (2) *Superphosphate* containing 16 percent available phosphoric acid was mixed, when so required, with

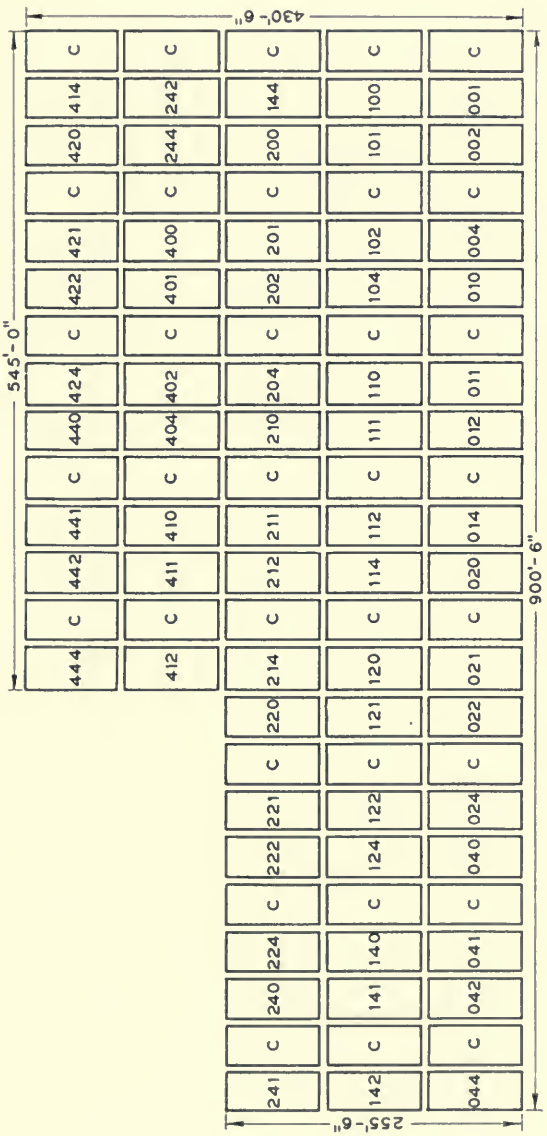

FIG. 2.—PLOT ARRANGEMENT IN FIELD 900

muriate of potash but never with nitrate. (3) *Muriate of potash* containing about 50 percent potassium oxid was used singly or in mixture with acid phosphate, as called for by the experiment.

Each year the fertilizers were analyzed and the treatments made up to the required amounts on the basis of the special analyses.

The fertilizer was broadcast by hand as uniformly and carefully as possible very early in the morning in order to eliminate the effect

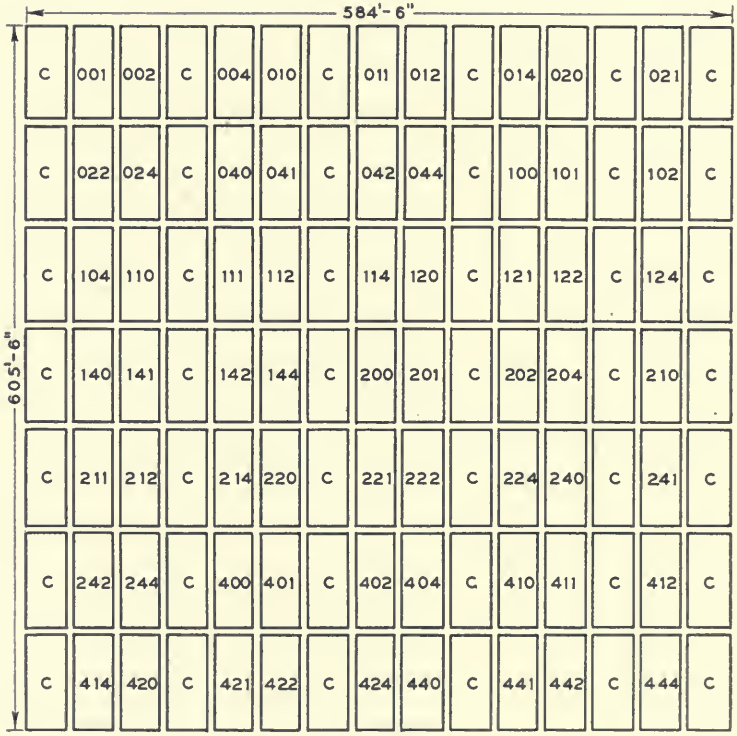

FIG. 3.—PLOT ARRANGEMENT IN FIELD 1000

of the wind. Applications were made to each sweet-corn crop, but no fertilizer was applied to either the small grain or clover. The amounts applied per four-year rotation may be readily determined, therefore, by doubling the designated treatments.

In an extensive experiment of this kind there was opportunity for almost endless variations in layout and treatments. The plan finally adopted closely resembled that suggested by Spillman,[44*] with the exception that the initial treatments were doubled a second time. Each of the three critical plant-food elements was applied in single, in

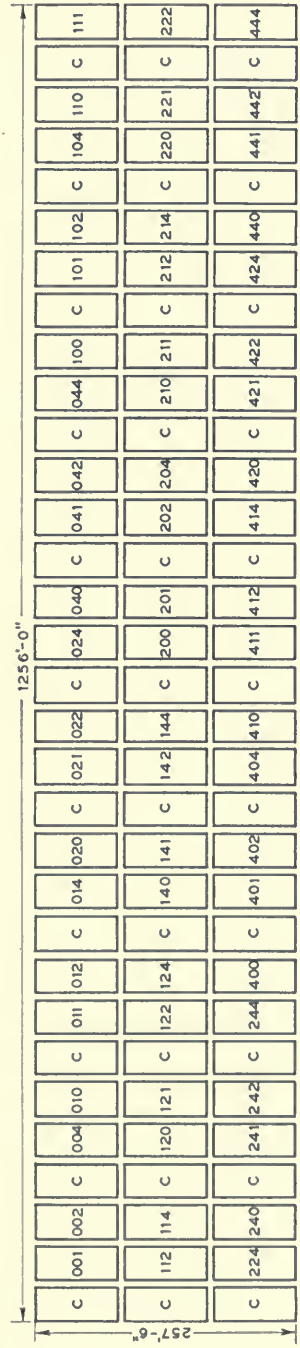

FIG. 4.—PLOT ARRANGEMENT IN FIELD 1300

double, and in quadruple dosages. A second element was then added to the first in single, double, and quadruple quantities. Finally the third element was added in the same proportions. A single fertilizer series consisted, therefore, of three dosages of the three elements applied in all the possible mathematical combinations. These totaled 63 separate treatments plus one with no fertilizer. Dosages were applied at the following rates per acre:

Nitrogen (15 percent nitrate of soda)

Single	50 pounds (7.5 pounds nitrogen)
Double	100 pounds (15 pounds nitrogen)
Quadruple	200 pounds (30 pounds nitrogen)

Phosphorus (16 percent superphosphate)

Single	200 pounds (32 pounds phosphorus pentaoxid)
Double	400 pounds (64 pounds phosphorus pentaoxid)
Quadruple	800 pounds (128 pounds phosphorus pentaoxid)

Potassium (50 percent muriate of potash)

Single	50 pounds (25 pounds potassium oxid)
Double	100 pounds (50 pounds potassium oxid)
Quadruple	200 pounds (100 pounds potassium oxid)

The quadruple dosage of each ingredient was assumed to be in excess of actual requirements. The single dosage was believed to represent a minimum and the double dosage an optimum. The results discussed later show that these assumptions were not correct in many cases, and that the real maximum was somewhere beyond the actual treatment.

One advantage of the series of treatments recommended by Spillman[44*] is the large number of direct comparisons possible. In determining the effect of any one of the three single elements, 48 possible comparisons are involved. Sixteen comparisons may be made where any two elements vary, and four comparisons where all three vary.

A summary showing, in terms of actual plant-food elements per acre, the individual fertilizer ingredients applied to each plot is given in Table 1. For the benefit of readers to whom this designation is unfamiliar, the applications are also expressed in terms of the nearest commercial fertilizer combinations. The slight discrepancy caused thereby is indicated. Many of the commercial combinations are not readily obtainable on the market, but it is usually possible to purchase similar ones. For example, if one wishes to apply an 0-16-6 fertilizer at the rate of 400 pounds an acre and cannot purchase this analysis, an 0-10-4, which is on the recommended list of standard fertilizer combinations according to Merz and Ross,[38*] may be substituted at the rate of 650 pounds an acre. Many other possible substitutions

TABLE 1.—FERTILIZER TREATMENTS PER ACRE: PLANT FOOD ACTUALLY APPLIED AND THE NEAREST EQUIVALENT APPLICATION IN TERMS OF STANDARD FORMULAE

Code designation for treatment	Treatment in terms of actual plant food			Treatment in terms of nearest commercial fertilizer formula		Deviation[a] of fertilizer formula from amount actually applied	
	Nitrogen	P_2O_5	K_2O	Amount	Formula	Nitrogen	K_2O
	lbs.	*lbs.*	*lbs.*	*lbs.*	*N-P-K*	*lbs.*	*lbs.*
001	...	...	25	50	0-0-50	...	...
002	...	...	50	100	0-0-50	...	...
004	...	...	100	200	0-0-50	...	...
010	...	32	...	200	0-16-0	...	...
011	...	32	25	200	0-16-12	...	−1
012	...	32	50	200	0-16-24	...	−2
014	...	32	100	400	0-8-24	...	−4
020	...	64	...	400	0-16-0	...	...
021	...	64	25	400	0-16-6	...	−1
022	...	64	50	400	0-16-12	...	−2
024	...	64	100	400	0-16-24	...	−4
040	...	128	...	800	0-16-0	...	...
041	...	128	25	800	0-16-3	...	−1
042	...	128	50	800	0-16-6	...	−2
044	...	128	100	800	0-16-12	...	−4
100	7.5	...	...	50	15-0-0	...	...
101	7.5	...	25	200	4-0-12	.5	−1
102	7.5	...	50	200	4-0-24	.5	−2
104	7.5	...	100	400	2-0-24	.5	−4
110	7.5	32	...	200	4-16-0	.5	...
111	7.5	32	25	200	4-16-12	.5	−1
112	7.5	32	50	200	4-16-24	.5	−2
114	7.5	32	100	400	2-8-24	.5	−4
120	7.5	64	...	400	2-16-0	.5	...
121	7.5	64	25	400	2-16-6	.5	−1
122	7.5	64	50	400	2-16-12	.5	−2
124	7.5	64	100	400	2-16-24	.5	−4
140	7.5	128	...	800	1-16-0	.5	...
141	7.5	128	25	800	1-16-3	.5	−1
142	7.5	128	50	800	1-16-6	.5	−2
144	7.5	128	100	800	1-16-12	.5	−4
200	15	...	...	100	15-0-0	...	...
201	15	...	25	200	8-0-12	1	−1
202	15	...	50	200	8-0-24	1	−2
204	15	...	100	400	4-0-24	1	−4
210	15	32	...	200	8-16-0	1	...
211	15	32	25	200	8-16-12	1	−1
212	15	32	50	200	8-16-24	1	−2
214	15	32	100	400	4-8-24	1	−4
220	15	64	...	400	4-16-0	1	...
221	15	64	25	400	4-16-6	1	−1
222	15	64	50	400	4-16-12	1	−2
224	15	64	100	400	4-16-24	1	−4
240	15	128	...	800	2-16-0	1	...
241	15	128	25	800	2-16-3	1	−1
242	15	128	50	800	2-16-6	1	−2
244	15	128	100	800	2-16-12	1	−4
400	30	...	...	200	15-0-0	...	...
401	30	...	25	375	8-0-7	...	1.25
402	30	...	50	375	8-0-14	...	2.50
404	30	...	100	375	8-0-28	...	5.00
410	30	32	...	200	15-16-0	...	...
411	30	32	25	200	15-16-12	...	−1
412	30	32	50	200	15-16-24	...	−2
414	30	32	100	400	8-8-24	2	−4
420	30	64	...	400	8-16-0	2	...
421	30	64	25	400	8-16-6	2	−1
422	30	64	50	400	8-16-12	2	−2
424	30	64	100	400	8-16-24	2	−4
440	30	128	...	800	4-16-0	2	...
441	30	128	25	800	4-16-3	2	−1
442	30	128	50	800	4-16-6	2	−2
444	30	128	100	800	4-16-12	2	−4

[a]No deviation from the formulae occurred in the amounts of P_2O_5 actually applied.

could be cited. As it is not possible to determine, by means of empirical experiments such as these, the exact quantity of each element required by the plant, reliable statements cannot be made as to whether or not a slight variation in the quantities applied would affect yields in any way. It is reasonably safe to assume, however, that a minor change in proportion or quantity would have but slight effect on the results, especially since plant requirements vary from season to season and from field to field.

Methods of Presenting Experimental Data

Methods of Calculation.—The only corrections made for soil variations were obtained by comparing the yield of each treated plot with that of the adjacent check.

Treatments have been paired in each case with adjacent checks, and odds showing the significance of mean differences in yield have been obtained by the use of Student's method.[48,49*] The odds are probably more important than the actual mean differences in determining the significance of mean increases in yield. When the odds are above 30:1 it may be assumed that certainty is being approached and that there is a real difference in the yields due to fertilizer. When the odds are less than 30:1, the differences in yield probably indicate directional tendencies only.

The preliminary experimental results obtained in 1922 have been omitted from all calculations.

Definitions.—The term "marketable ears" frequently referred to in the tables means ears which, under conditions in Illinois, are accepted as suitable for canning. All smutted and rotten ears and those of abnormal shape were excluded regardless of size. Otherwise the grading was based entirely on size and on how well the ears were filled. Badly filled ears were classed as culls, and their weights are not included here.

Reading Tables.—In the subsequent discussion and in the tabulated data constant reference must be made to specific treatments. To describe these in detail each time it is necessary to mention one of them would be extremely cumbersome and tiresome to read. Accordingly the authors have employed for this purpose the very simple code which they used in taking notes.

Of the three dosages of each of the three principal plant nutrients applied, the first is single and is designated by the figure "1;" the second dosage is double the first and is designated by "2;" while the third dosage is quadruple the first and is designated by "4."

The generally accepted order of stating commercial fertilizer combinations is nitrogen-phosphorus-potassium (N-P-K). This order has been retained in the code (Table 1). Accordingly, Treatment 400 means that 30 pounds of nitrogen per acre was applied, Treatment 040 means 128 pounds of phosphoric acid per acre; and Treatment 004 means 100 pounds of potash (K_2O) per acre. Treatment 444 means that all three elements were combined and the combination applied in quadruple quantities.

Chemical symbols also have been used in the tables for the sake of brevity. "N" stands for the element nitrogen contained in sodium nitrate. The formula P_2O_5 (phosphorus pentaoxid) is the usual method of expressing the percentage of available phosphorus in phosphatic fertilizers. Potash is designated as K_2O (potassium oxid), representing the available potassium in potassium chlorid, or muriate of potash as it is called.

Tables 2 to 9 inclusive, 11 to 13, 20 to 23, and 36 are so arranged that they may be read vertically or horizontally. Thus Table 2 read horizontally shows the results that were obtained by increasing nitrogen and keeping phosphorus constant, as noted in the left-hand column. Read vertically, Table 2 gives the results due to increasing phosphorus and keeping nitrogen constant in the quantity noted at the head of each column.

The tables involving combinations of the three critical nutrient elements will be confusing unless their construction is carefully noted and remembered. Table 5 is a good example. The treatment indicated at the top of each column of increases and odds is not complete; it describes the dosages of only two of the three elements. The dosage of the third or varying element in each column is indicated by x, and the value of x is obtained by referring to the treatments indicated in the extreme left-hand column. Similarly, the treatment indicated in each row of the left-hand column is incomplete, and the value of x is obtained by referring to the treatments indicated at the top of the columns of increases and odds. Thus, the first line of Table 5 read horizontally gives the increases from Treatments 002, 102, 202, and 402. Such groups of four treatments in which the dosages of two elements are constant and the third ranges from "0" to "4" are designated as "sets." This particular set of treatments is ordinarily described in the subsequent text as Set $x02$. The second line read horizontally gives the results from Treatments 012, 112, 212, 412 (Set $x12$). The first vertical column of results gives the results from Treatments 002, 012, 022, 042 (Set $0x2$), and the second vertical

column of results gives the results from Treatments 102, 112, 122, 142 (Set 1*x*2).

In the subsequent text consideration is limited to the *differences* between the treated plots and the adjacent checks. For *total yields* reference must be made to Table 39, Appendix. Each difference between treated plot and check is itself a mean or average difference involving results obtained from several plots over several years. The odds are calculated, as stated previously, according to Student's method.

Methods of Analyzing the Results.—The large number of treatments included in this experiment should make it possible to determine rather definitely the fertilizer requirements of sweet corn on the Illinois soils under test; but the very comprehensiveness of the experiment serves to bring out the complexity of a problem which superficially seems relatively simple. To illustrate:

If only a half dozen or so treatments were involved in the experiment, there would be no trouble ordinarily in determining quite conclusively the optimum one, provided the experiments were repeated often enough. However, with 63 fertilizer treatments, the number here involved, choosing the optimum ratios is quite another matter. A glance at the detail data on yields given in Table 39, Appendix, shows why this is so. Treatment 144, for example, which is credited with an increase of 55.58 percent over the check plot in the weight of marketable ears, outyielded all the other treatments by a considerable margin. Is this treatment, then, the best of the sixty-three? If not, which treatment is the best?

As a partial answer to the above questions, the probable errors of the differences between the percentage increases of the treatments giving the largest and the second-largest increases over their respective check plots have been calculated, with the following results:

	Percentage increase
Treatment 144	55.58 ± 7.7
Treatment 122	44.47 ± 8.1
Difference	11.11 ± 11.2

A difference of 11.11 that has a probable error of 11.2 is not significant, and we must therefore conclude that Treatment 144 was not significantly better than Treatment 122. In all, 19 of the treatments listed in Table 39, Appendix, showed increases, in ton yields of marketable ears, of more than 30 percent over the respective check plots. The treatments may be ranked as follows on the basis of percentage increases:

Rank	Treatment	Percentage increase over check	Rank	Treatment	Percentage increase over check
1	144	55.58 ± 7.7	11	121	34.47 ± 4.7
2	122	44.47 ± 8.1	12	141	32.76 ± 6.3
3	044	43.50 ± 6.5	13	422	32.04 ± 3.2
4	142	40.11 ± 5.8	14	212	31.95 ± 6.3
5	420	38.98 ± 4.4	15	221	31.92 ± 5.2
6	114	38.54 ± 5.1	16	220	31.50 ± 4.8
7	041	37.41 ± 4.8	17	124	31.11 ± 5.3
8	042	37.28 ± 4.5	18	140	30.12 ± 6.1
9	424	35.53 ± 2.5		414	30.12 ± 7.0
10	112	34.73 ± 5.3			

All the above increases are significant,—that is, all are more than 3.2 times their probable errors,—but the differences between the increases are not significant. Comparison of the increases produced by the treatments giving the highest and lowest percentage increases in this group of 19 shows the following:

	Percentage increase
Treatment 144	55.58 ± 7.7
Treatment 414	30.12 ± 7.0
Difference	25.46 ± 10.4

The difference between these increases, 25.46 ± 10.4, is only 2.4 times its probable error and therefore is not significant. Any one of the 19 treatments may therefore be the optimum.

It is clear that a highly critical analysis of the data is necessary in order to determine the optimum fertilizer ratio or ratios. It would be very difficult, if not impossible, to make such a determination by the usual methods employed by investigators. The device which may be used is the mathematical relationship existing between the treatments. If only four treatments were under consideration, the following interpretation could be made from the increases in yields of marketable ears expressed as percentages (Table 39, Appendix).

	Percentage increase	Percentage increase due to phosphorus (subtract increase with Tr. 001 from that of each succeeding treatment)
Treatment 001	−8.98 ± 2.7	.....
Treatment 011	13.91 ± 4.0	22.89 ± 4.8
Treatment 021	18.75 ± 4.3	27.73 ± 5.1
Treatment 041	37.41 ± 4.8	46.39 ± 5.5

Among these four treatments, the increases due to phosphorus became successively larger with the larger dosages. In order that the percentage increases due to phosphorus may be distinguished from the total percentage increases, the phosphorus percentages will be called phosphorus "efficiency factors." Thus the efficiency of phosphorus in

Treatment 041 is 46.39 ± 5.5 percent. The potash efficiency in this group of treatments may be determined as follows:

Treatment (P-K)	*Percentage increase*	*Treatment* (P)	*Percentage increase*	*Difference (potash efficiency)*
011.....	13.91 ± 4.0	010.....	22.63 ± 4.8	−8.72 ± 6.2
021.....	18.75 ± 4.3	020.....	10.02 ± 2.7	8.73 ± 5.1
041.....	37.41 ± 4.8	040.....	19.45 ± 4.0	17.96 ± 6.2

Thus the potash efficiency in Treatments 011, 021, and 041 (right-hand column above) was not statistically significant tho there was a very sharp upward trend in the efficiency of this element as successively larger amounts of phosphorus were added. The "efficiency factor" method of analyzing the data will be used to supplement the conventional analysis in the subsequent discussion. It will be used only with data involving *weights of marketable ears,* altho the data on numbers of ears and weights of green fodder could be interpreted in the same way.

The efficiency factor for each element in each treatment is shown in Table 40, Appendix. The probable error for each efficiency factor has been calculated according to the formula

$$\text{P.E.} = \sqrt{a^2 + b^2 + 2r_{ab}ab}$$

where a and b represent the probable errors of the percentage increases in yield resulting from the two treatments being subtracted, and r represents the correlation between a and b. Since it is assumed that $r = 0$, the formula becomes

$$\text{P.E.} = \sqrt{a^2 + b^2}$$

The probable errors of the increased yields expressed as percentages were obtained according to the formula

$$\text{P.E.} = \frac{\pm .6745 \text{ S.D.}}{\sqrt{n}}$$

in which S.D. means the standard deviation and n the number of observations.

It is apparent, of course, that a very large number of comparisons are possible. Each yield increase is itself the mean difference between 12 annual crop yields and 12 adjacent check yields. This result is in turn subtracted from another similarly obtained; the difference is the efficiency factor. Thus each efficiency factor is the result of calculations involving 48 separate plot yields. These factors are present in 12 different groups, each group consisting of 16 treatments. In order to simplify the tables, only the mean factors, obtained by averaging

the results from each set of four treatments in which two elements were quiescent, are used. In specifying the set, the changing element is represented as x. An explanation of the way in which the top line of Table 14 is derived will serve as an example:

Treatment	*N efficiency factor*	*Treatment*	*N efficiency factor*	*Treatment*	*N efficiency factor*
100.....	5.51 ± 5.0	200.....	−2.91 ± 2.2	400.....	−4.85 ± 8.1
101.....	−3.43 ± 7.0	201.....	1.81 ± 3.2	401.....	26.36 ± 4.3
102.....	.26 ± 4.9	202.....	−4.54 ± 5.0	402.....	−4.64 ± 4.6
104.....	−8.28 ± 5.0	204.....	1.74 ± 6.7	404.....	−5.82 ± 4.9
(*Set*)	(*Mean*)	(*Set*)	(*Mean*)	(*Set*)	(*Mean*)
10x.....	−1.48 ± 2.8	20x.....	−.98 ± 2.3	40x.....	2.76 ± 2.8

In each set the nitrogen dosage is quiescent, the phosphorus dosage absent (tho in a different set of treatments it also might be quiescent), whereas the potash dosages are changing. As between three such sets of treatments, however, we have a reverse arrangement: nitrogen becomes the changing element while potash and phosphorus are the common, or quiescent, elements. Thus x indicates the changing element within a set of treatments, tho it becomes the symbol for one of the two quiescent elements among a group of sets.

The factors for the individual treatments are taken from Table 40, Appendix, and the probable errors for the mean treatments are calculated according to the following formula:

$$\text{P.E.} = \frac{1}{n}\sqrt{a^2+b^2+c^2+d^2}$$

in which a, b, c, and d represent the probable errors of individual factors and n the number involved, which is 4 in each case.

Since comparison of the means alone may lead to errors, the modes are likewise compared. For instance, if the increases from Set 10x listed above are assumed to be a curve, Treatment 100 would be the mode, because it has the largest efficiency factor. The respective modes[a] may be compared in the same manner as the means, as shown in Table 15, among others. The maximum mean increases in yields in Table 16, however, are also modes which have been obtained from Table 40, Appendix, in a similar manner, the difference being that they are actual maximum increases in the mean yields instead of maximum efficiency factors.

Thus there are three separate methods of interpreting the data, and these will be used thruout the discussions of experimental results.

The validity of the efficiency-factor method had been discussed at length in a separate paper by the senior author, Huelsen.[31*] The

[a]As used here and in subsequent portions of the text, "mode" means the point at which the maximum increase occurred.

method of evaluating efficiency factors by comparing the modes of individual curves is, however, presented here for the first time.

An attempt was also made to interpret the reciprocal relations between the nutrient elements in physico-chemical terms. Because of inability to secure appropriate supporting evidence from analytical work, however, the physico-chemical interpretation was made entirely by inference, and the results, altho they support the interpretation by efficiency factors, are not included in this report of the experiments.

INFLUENCE OF FERTILIZERS ON YIELD

In the following pages the effects which the three major nutrient elements had on sweet-corn yields, when used alone and in the various combinations, are traced. All figures representing increases in yields indicate increases over the check plots.

EFFECTS OF NITROGEN

The effects of nitrate of soda, when applied alone and in combination with one or both of the other elements, have been summarized in the accompanying tables. All comparisons are obtained by reading horizontally across the tables.

Nitrogen, used either alone or in combination with phosphorus or potash, or both, as a fertilizer for sweet corn, appears to have certain limitations, and the optimum combinations of potash and phosphorus to be used with side-dressed nitrogen are not readily discernible.

Nitrogen Alone

Sodium nitrate applied in the rotation as a side dressing without an accompanying basal treatment of minerals produced variable effects on yield ranging from decided decreases to definite increases (Table 2). With no clover in the rotation, an initial treatment of 50 pounds of nitrate per acre resulted in a small increase in yield, but heavier applications gave lower yields than the adjacent checks. In both the first and second years after clover, nitrate had no material effect on yields.

The means of the plots receiving nitrate only, including all such plots in all three positions in the rotation, show increases in the weights of ears amounting to 5.51 percent for Treatment 100, — 2.91 percent for Treatment 200, and — 4.85 percent for Treatment 400 (Section A, Tables 11 and 12). The odds thruout are too small to indicate anything more than a tendency.

According to the results herein obtained, growers would not be justified in side-dressing nitrate of soda when it is the only treatment.

TABLE 2.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND SUPERPHOSPHATE

(Figures indicate mean increases per acre over adjacent check plots)

Phosphorus series[a]	Nitrogen series[a]							
	0x0	1x0	2x0	4x0	0x0	1x0	2x0	4x0
	Number of ears				Tons marketable ears			
No clover in rotation								
x00	....	613	− 192	−666	....	.136	−.092	−.278
Odds	....	23:1	1:1	4:1	....	15:1	2:1	4:1
x10	1017	849	−1152	1616	.296	.195	−.359	.578
Odds	70:1	21:1	12:1	39:1	56:1	11:1	13:1	58:1
x20	1765	1805	1380	2842	.370	.391	.467	.914
Odds	12:1	46:1	29:1	35:1	10:1	16:1	27:1	66:1
x40	1239	1327	546	148	.345	.361	.235	.027
Odds	5:1	4:1	4:1	1:1	5:1	3:1	29:1	1:1
First year after clover								
x00	....	−186	28	49	....	−.060	−.032	.028
Odds	....	2:1	<1:1	1:1	....	2:1	1:1	4:1
x10	1491	731	457	1236	.448	.246	.283	.314
Odds	3:1	61:1	2:1	8:1	12:1	30:1	4:1	5:1
x20	444	1334	1540	1459	.118	.490	.564	.595
Odds	2:1	22:1	19:1	11:1	3:1	17:1	17:1	22:1
x40	1099	1879	1541	849	.377	.636	.695	.310
Odds	13:1	10:1	29:1	5:1	9:1	11:1	25:1	5:1
Second year after clover								
x00	....	566	−414	−822	....	.234	−.056	−.162
Odds	....	3:1	3:1	5:1	....	3:1	2:1	3:1
x10	1561	748	662	−187	.422	.270	.189	.036
Odds	7:1	5:1	4:1	2:1	9:1	5:1	3:1	8:1
x20	369	1808	1596	1914	.248	.673	.552	.778
Odds	4:1	72:1	13:1	26:1	19:1	253:1	24:1	72:1
x40	1086	1930	2399	1960	.360	.716	.912	.672
Odds	13:1	27:1	38:1	3332:1	26:1	77:1	55:1	2499:1

[a]This table and similar subsequent tables may be read either vertically or horizontally. Read either way, treatment code numbers are obtained by replacing the symbol for the changing dosage (x) by the corresponding figure in the code designation at the top of the columns or in the column at the left.

Similar results from the use of nitrogen alone on various crops have been obtained by other investigators. Gardner, Noll, and Baker,[22*] for instance, in a 35-year rotation of corn, oats, wheat, and mixed hay found that nitrogen alone gave insignificant increases in the total yields of the four crops. On the other hand, Comin and Bushnell,[15*] in their experiments with sweet corn, found that nitrogen

gave larger increases when used alone than when used in combination with superphosphate. The results of the present experiments are probably more in accord with normal expectation on Illinois soils than are those of Comin and Bushnell.

Nitrogen Increasing, Phosphorus Constant

In fertilizers containing combinations of nitrogen and phosphorus, increases in yield due to nitrogen were much more consistent and were significantly greater than when nitrogen was used alone (Table 2).

With no clover in the rotation the largest and most consistent increases in yields from these combinations occurred in Set $x20$. Treatment 410 also gave a large increase in yield with significant odds, but in Set $x40$ the yield increases due to nitrate were smaller for the heavier dosages. During the first and also the second year after clover the yields increased in relation to the amount of nitrate applied in Set $x20$ and in Set $x40$ as far as Treatment 240. In Set $x10$ phosphorus alone (Treatment 010) gave larger increases in yield than any of the treatments containing nitrogen, but the odds are too small to be significant.

The means of the plots receiving treatments of nitrogen and phosphorus in combination, including all such plots in all positions in the rotation, show that the most consistent increases with significant odds occurred in Set $x20$ with the maximum increase at Treatment 420 (Section E, Tables 11 and 12).

Thus, altho sweet corn does not draw as heavily as field corn upon the available supply of phosphorus in the soil (Whiting[55*]), it is evident an application of at least 64 pounds of P_2O_5 per acre is necessary before nitrate becomes effective. W. H. Michaels, formerly of the Department of Horticulture, University of Illinois, in unpublished greenhouse pot-culture experiments with a P_7 inbred line of sweet corn found that successive dosages at the calculated acre-rate of 50, 150, and 250 pounds of 2-0-0 fertilizer made from sodium nitrate, gave, as compared with the check, increases in the green weights of 21-day-old seedlings of 22.2 percent, 15.6 percent, and 15.7 percent respectively. Gardner, Noll, and Baker[22*] found in experiments conducted in Pennsylvania, later confirmed by Gardner, Noll, and Lewis,[23*] that a plot receiving nitrogen and phosphorus yielded 34.1 percent more than the untreated checks, but one receiving nitrogen and potash yielded only 5.7 percent over the check. In these Pennsylvania experiments phosphorus was the limiting factor.

Results obtained from the use of combinations of nitrogen and potassium (reported on later pages) indicate that phosphorus was the limiting factor in the soils involved in these experiments. Since many of the soils in central Illinois contain large amounts of potassium (even tho mostly in unavailable form),[29*] a treatment of nitrogen and phosphorus might be expected to give considerable increase in yield. The sweet-corn plant utilizes potash in relatively large quantities, as Whiting[55*] has shown, and this element is probably very necessary during the period of maturation. The increases obtained by using nitrogen and phosphorus without potash might be explained on the assumption that the addition of nitrogen increases the absorption of potash by the plant. Breazeale's[11*] experiments show that this is what occurs when phosphorus is not the limiting factor.

Nitrogen Increasing, Potash Constant

With no clover in the rotation and during both the first and second year after clover, the effects of nitrogen-potash fertilizer combinations on yields were extremely variable, and showed no definite tendencies (Table 3). Only in Set *x*04 during the second year after clover did nitrate in these combinations result in definite increases; but the odds are not significant.

The mean increases in yield of the plots receiving nitrogen-potash combinations, including all such plots in all positions in the rotation, show that only Treatment 401 gave significant increases over the adjacent check (Section A of Tables 11 and 12).

According to the Illinois soil survey,[29*] total phosphorus is low in many soils of Champaign county. While this does not necessarily indicate that available phosphorus also is low, and altho sweet corn requires less phosphorus than field corn, according to Whiting,[55*] it is probable that available phosphorus was deficient in the soils of most of the plots to a sufficient extent to make phosphorus the limiting factor when nitrogen was used only with potash. It is therefore not surprising that nitrogen-potash combinations in these experiments gave variable results.

Nitrogen Increasing, Phosphorus and Potash Constant

The fertilizer analyses discussed under this heading are "complete," that is, they contain the three major plant-food elements. Comparisons made in each table involve horizontal readings, and the discussions are confined to effects of nitrogen where phosphorus and potash were held constant. At each position in the rotations six comparisons

TABLE 3.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND POTASSIUM CHLORID

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Nitrogen series							
	00x	10x	20x	40x	00x	10x	20x	40x
	Number of ears				Tons marketable ears			
No clover in rotation								
x00	....	613	−192	−666	....	.136	−.092	−.278
Odds	....	23:1	1:1	4:1	....	15:1	2:1	4:1
x01	−290	−889	596	243	−.097	−.300	.071	.114
Odds	3:1	4:1	3:1	9:1	4:1	4:1	2:1	6:1
x02	34	−667	188	1124	.014	−.458	.039	.209
Odds	2:1	11:1	1:1	5:1	2:1	5:1	4:1	14:1
x04	168	236	−1044	−902	.021	.022	−.399	−.331
Odds	3:1	2:1	2:1	9:1	1:1	2:1	215:1	25:1
First year after clover								
x00	....	−186	28	49	....	−.060	−.032	.028
Odds	....	2:1	<1:1	1:1	....	2:1	1:1	4:1
x01	−941	−634	−857	1249	−.336	−.197	−.264	.475
Odds	37:1	2:1	31:1	155:1	24:1	2:1	66:1	28:1
x02	101	356	−877	315	.030	.181	−.302	.054
Odds	2:1	3:1	6:1	3:1	2:1	4:1	6:1	2:1
x04	646	−768	731	−485	.251	−.354	.287	−.131
Odds	38:1	12:1	3:1	4:1	160:1	28:1	6:1	3:1
Second year after clover								
x00	....	566	−414	−822	....	.234	−.056	−.162
Odds	....	3:1	3:1	5:1	....	3:1	2:1	3:1
x01	−314	−1379	−591	768	−.086	−.224	−.108	.295
Odds	3:1	5:1	30:1	5:1	2:1	3:1	12:1	10:1
x02	−172	424	197	−1450	.043	.229	.187	−.405
Odds	2:1	4:1	1:1	16:1	2:1	5:1	5:1	6:1
x04	−495	399	550	1000	−.130	.144	.216	.261
Odds	3:1	2:1	2:1	5:1	2:1	2:1	2:1	3:1

are possible where nitrogen varied in combination with constants of the four different dosages of phosphorus and potash. Each "comparison" involves 16 treatment combinations.

No Clover in Rotation.—(1) K_2O 25 pounds per acre constant (Table 4). In only a few treatments (Nos. 111, 211, 121, and 221) did increasing the amount of nitrate of soda in combination with a constant amount of phosphorus (P_2O_5) give increases in yield larger than those in which nitrate was omitted (Nos. 011, 021, and 041).

TABLE 4.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND SUPERPHOSPHATE WITH A SINGLE DOSAGE OF POTASSIUM CHLORID CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Phosphorus series	Nitrogen series							
	0x1	1x1	2x1	4x1	0x1	1x1	2x1	4x1
	Number of ears				Tons marketable ears			
No clover in rotation								
x01	−290	−889	596	243	−.097	−.300	.071	.114
Odds	3:1	4:1	3:1	9:1	4:1	4:1	2:1	6:1
x11	323	566	903	34	.074	.176	.290	−.074
Odds	2:1	23:1	6:1	<1:1	2:1	24:1	18:1	2:1
x21	2835	1165	1253	−236	.869	.337	.382	−.103
Odds	10:1	7:1	603:1	2:1	16:1	12:1	57:1	2:1
x41	2397	−101	−229	1650	.678	−.046	.005	.566
Odds	603:1	1:1	2:1	26:1	807:1	2:1	<1:1	74:1
First year after clover								
x01	−941	−634	−857	1249	−.336	−.197	−.264	.475
Odds	37:1	2:1	31:1	155:1	24:1	2:1	66:1	28:1
x11	1321	824	792	824	.425	.175	.201	.342
Odds	45:1	16:1	4:1	4:1	61:1	3:1	2:1	6:1
x21	760	1636	1657	1596	.292	.527	.601	.550
Odds	4:1	28:1	46:1	10:1	6:1	48:1	30:1	7:1
x41	1915	1835	1592	1200	.741	.742	.547	.544
Odds	40:1	79:1	22:1	21:1	23:1	124:1	21:1	26:1
Second year after clover								
x01	−314	−1379	−591	768	−.086	−.224	−.108	.295
Odds	3:1	5:1	30:1	5:1	2:1	3:1	12:1	10:1
x11	708	520	838	1410	.145	.182	.325	.583
Odds	5:1	304:1	61:1	19:1	3:1	19:1	34:1	20:1
x21	359	2667	2030	1717	.242	.968	.742	.658
Odds	4:1	43:1	11:1	14:1	11:1	58:1	13:1	38:1
x41	1424	2546	2784	1636	.584	1.060	1.027	.608
Odds	96:1	16:1	45:1	78:1	100:1	24:1	108:1	158:1

(2) K_2O 50 pounds per acre constant (Table 5). Nitrate gave scattered increases in yield, but there was no consistent tendency toward increases.

(3) K_2O 100 pounds per acre constant (Table 6). Nitrate gave scattered increases in yield, but exhibited no definite tendency.

(4) P_2O_5 32 pounds per acre constant (Table 7). Nitrate gave scattered increases in yield, but exhibited no definite tendency.

(5) P_2O_5 64 pounds per acre constant (Table 8). A slight tendency to respond to increasing dosages of nitrate was noticeable, but the tendency

TABLE 5.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND SUPERPHOSPHATE WITH A DOUBLE DOSAGE OF POTASSIUM CHLORID CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Phosphorus series	Nitrogen series							
	0x2	1x2	2x2	4x2	0x2	1x2	2x2	4x2
	Number of ears				Tons marketable ears			
No clover in rotation								
x02	34	−667	188	1124	.014	−.458	.039	.209
Odds	2:1	11:1	1:1	5:1	2:1	5:1	4:1	14:1
x12	2108	727	1529	364	.573	.255	.395	.051
Odds	23:1	11:1	806:1	2:1	24:1	15:1	59:1	1:1
x22	1057	1421	491	1637	.022	.397	.178	.458
Odds	65:1	27:1	3:1	32:1	1:1	3:1	4:1	28:1
x42	1596	1906	−67	−6	.430	.603	.062	.071
Odds	73:1	41:1	1:1	<1:1	42:1	32:1	2:1	1:1
First year after clover								
x02	101	356	−877	315	.030	.181	−.302	.054
Odds	2:1	3:1	6:1	3:1	2:1	4:1	6:1	2:1
x12	145	1754	1418	590	.061	.622	.565	.333
Odds	1:1	51:1	14:1	6:1	1:1	25:1	15:1	12:1
x22	1685	2768	1152	1555	.530	.927	.527	.429
Odds	14:1	45:1	19:1	239:1	10:1	37:1	30:1	79:1
x42	2198	1172	1980	448	.809	.687	.735	.231
Odds	79:1	10:1	6:1	5:1	47:1	22:1	6:1	9:1
Second year after clover								
x02	−172	424	197	−1450	.043	.229	.187	−.405
Odds	2:1	4:1	1:1	16:1	2:1	5:1	5:1	6:1
x12	1450	2465	1868	1076	.510	.827	.632	.294
Odds	22:1	46:1	9:1	22:1	11:1	48:1	9:1	25:1
x22	1531	2430	2864	2263	.548	.872	1.000	.881
Odds	48:1	14:1	49:1	157:1	63:1	9:1	46:1	510:1
x42	1818	2298	1949	1677	.716	1.081	.725	.659
Odds	18:1	18:1	40:1	42:1	85:1	29:1	90:1	237:1

was not pronounced enough to afford a basis for definite conclusions. Where potash was entirely omitted (Set *x*20), nitrate was very effective in increasing the yields.

(6) P_2O_5 128 pounds per acre constant (Table 9). Scattered increases, sometimes quite large, were again obtained.

First Year After Clover.—(1) K_2O 25 pounds per acre constant (Table 4). Nitrate showed a definite tendency to increase the yields in Set *x*21 but not elsewhere.

(2) K_2O 50 pounds per acre constant (Table 5). In combinations such

TABLE 6.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND SUPERPHOSPHATE WITH A QUADRUPLE DOSAGE OF POTASSIUM CHLORID CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Phosphorus series	Nitrogen series							
	0x4	1x4	2x4	4x4	0x4	1x4	2x4	4x4
	Number of ears				Tons marketable ears			
No clover in rotation								
x04	168	236	−1044	−902	.021	.022	−.399	−.331
Odds	3:1	2:1	2:1	9:1	1:1	2:1	215:1	25:1
x14	1172	2222	876	875	.236	.636	.157	.358
Odds	10:1	7:1	13:1	3:1	5:1	18:1	11:1	6:1
x24	646	1185	−1010	2957	.209	.381	−.357	.804
Odds	7:1	8:1	18:1	>9999:1	5:1	17:1	17:1	10:1
x44	1825	2074	1414	−909	.450	.731	.661	−.251
Odds	7:1	12:1	74:1	8:1	5:1	21:1	2064:1	5:1
First year after clover								
x04	646	−768	731	−485	.251	−.354	.287	−.131
Odds	38:1	12:1	3:1	4:1	160:1	28:1	6:1	3:1
x14	1204	1394	1289	1132	.439	.496	.479	.371
Odds	45:1	44:1	8:1	5:1	41:1	28:1	9:1	4:1
x24	1103	2388	667	1676	.445	.680	.379	.557
Odds	31:1	24:1	4:1	505:1	27:1	20:1	5:1	495:1
x44	1774	2408	1346	586	.752	.955	.523	.212
Odds	20:1	14:1	14:1	9:1	22:1	24:1	27:1	6:1
Second year after clover								
x04	−495	399	550	1000	−.130	.144	.216	.261
Odds	3:1	2:1	2:1	5:1	2:1	2:1	2:1	3:1
x14	2450	1884	1864	2541	.832	.740	.624	.984
Odds	15:1	24:1	41:1	41:1	15:1	30:1	40:1	65:1
x24	1697	1848	2672	1556	.658	.460	.908	.654
Odds	25:1	13:1	56:1	27:1	39:1	34:1	78:1	60:1
x44	3000	3051	1566	835	1.052	1.171	.718	.427
Odds	68:1	36:1	48:1	55:1	134:1	39:1	46:1	39:1

as Treatments 112 and 122, the addition of nitrate increased the yields over Treatments 012 and 022 respectively. In other combinations nitrate gave no increases.

(3) K_2O 100 pounds per acre constant (Table 6). The addition of 50 pounds of sodium nitrate per acre (Treatments 114, 124, and 144) gave increases over corresponding treatments where nitrate was omitted. Larger additions of nitrate failed, however, to give further increases.

(4) P_2O_5 32 pounds per acre constant (Table 7). In two instances,

TABLE 7.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND POTASSIUM CHLORID WITH A SINGLE DOSAGE OF SUPERPHOSPHATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Nitrogen series							
	01*x*	11*x*	21*x*	41*x*	01*x*	11*x*	21*x*	41*x*
	Number of ears				Tons marketable ears			
No clover in rotation								
*x*10	1017	849	−1152	1616	.296	.195	−.359	.578
Odds	70:1	21:1	12:1	39:1	56:1	11:1	13:1	58:1
*x*11	323	566	903	34	.074	.176	.290	−.074
Odds	2:1	23:1	6:1	<1:1	2:1	24:1	18:1	2:1
*x*12	2108	727	1529	364	.573	.255	.395	.051
Odds	23:1	11:1	806:1	2:1	24:1	15:1	59:1	1:1
*x*14	1172	2222	876	875	.236	.636	.157	.358
Odds	10:1	7:1	13:1	3:1	5:1	18:1	11:1	6:1
First year after clover								
*x*10	1491	731	457	1236	.448	.246	.283	.314
Odds	3:1	61:1	2:1	8:1	12:1	30:1	4:1	5:1
*x*11	1321	824	792	824	.425	.175	.201	.342
Odds	45:1	16:1	4:1	4:1	61:1	3:1	2:1	6:1
*x*12	145	1754	1418	590	.061	.622	.565	.333
Odds	1:1	51:1	14:1	6:1	1:1	25:1	15:1	12:1
*x*14	1204	1394	1289	1132	.439	.496	.479	.371
Odds	45:1	44:1	8:1	5:1	41:1	28:1	9:1	4:1
Second year after clover								
*x*10	1561	748	662	−187	.422	.270	.189	.036
Odds	7:1	5:1	4:1	2:1	9:1	5:1	3:1	8:1
*x*11	708	520	838	1410	.145	.182	.325	.583
Odds	5:1	304:1	61:1	19:1	3:1	19:1	34:1	20:1
*x*12	1450	2465	1868	1076	.510	.827	.632	.294
Odds	22:1	46:1	9:1	22:1	11:1	48:1	9:1	25:1
*x*14	2450	1884	1864	2541	.832	.740	.624	.984
Odds	15:1	24:1	41:1	41:1	15:1	30:1	40:1	65:1

Treatments 112 and 114, nitrate increased yields over the respective treatments without nitrate. However, no definite trend developed.

(5) P_2O_5 64 pounds per acre constant (Table 8). In Set *x*21 nitrate gave successively larger increases in yield where 50 to 100 pounds were applied per acre, but 50 pounds per acre gave the largest increases in the sets having constants of 50 and 100 pounds K_2O per acre.

(6) P_2O_5 128 pounds per acre constant (Table 9). Nitrate increased the yields materially in only two instances (Treatment 140 and 144), and even here the odds indicate little more than a tendency.

TABLE 8.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND POTASSIUM CHLORID WITH A DOUBLE DOSAGE OF SUPERPHOSPHATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Nitrogen series							
	02x	12x	22x	42x	02x	12x	22x	42x
	Number of ears				Tons marketable ears			
No clover in rotation								
x20	1765	1805	1380	2842	.370	.391	.467	.914
Odds	12:1	46:1	29:1	35:1	10:1	16:1	27:1	66:1
x21	2835	1165	1253	−236	.869	.337	.382	−.103
Odds	10:1	7:1	603:1	2:1	16:1	12:1	57:1	2:1
x22	1057	1421	491	1637	.022	.397	.178	.458
Odds	65:1	27:1	3:1	32:1	1:1	3:1	4:1	28:1
x24	646	1185	−1010	2957	.209	.381	−.357	.804
Odds	7:1	8:1	18:1	>9999:1	5:1	17:1	17:1	10:1
First year after clover								
x20	444	1334	1540	1459	.118	.490	.564	.595
Odds	2:1	22:1	19:1	11:1	3:1	17:1	17:1	22:1
x21	760	1636	1657	1596	.292	.527	.601	.550
Odds	4:1	28:1	46:1	10:1	6:1	48:1	30:1	7:1
x22	1685	2768	1152	1555	.530	.927	.527	.429
Odds	14:1	45:1	19:1	239:1	10:1	37:1	30:1	79:1
x24	1103	2388	667	1676	.445	.680	.379	.557
Odds	31:1	24:1	4:1	505:1	27:1	20:1	5:1	495:1
Second year after clover								
x20	369	1808	1596	1914	.248	.673	.552	.778
Odds	4:1	72:1	13:1	26:1	19:1	253:1	24:1	72:1
x21	359	2667	2030	1717	.242	.968	.742	.658
Odds	4:1	43:1	11:1	14:1	11:1	58:1	13:1	38:1
x22	1531	2430	2864	2263	.548	.872	1.000	.881
Odds	48:1	14:1	49:1	157:1	63:1	9:1	46:1	510:1
x24	1697	1848	2672	1556	.658	.460	.908	.654
Odds	25:1	13:1	56:1	27:1	39:1	34:1	78:1	60:1

Second Year After Clover.—(1) K_2O 25 pounds per acre constant (Table 4). In Set x11 the increases in yield, on the weight basis, became successively larger as nitrate was increased. An application of 50 pounds of nitrate per acre gave the largest increases, on the basis of weights of marketable ears, where the phosphorus constants were respectively 64 and 128 pounds P_2O_5 per acre.

(2) K_2O 50 pounds per acre constant (Table 5). Nitrate in combinations containing 32 and 128 pounds P_2O_5 per acre gave the largest in-

TABLE 9.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SODIUM NITRATE AND POTASSIUM CHLORID WITH A QUADRUPLE DOSAGE OF SUPERPHOSPHATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Nitrogen series							
	04x	14x	24x	44x	04x	14x	24x	44x
	Number of ears				Tons marketable ears			
No clover in rotation								
x40	1239	1327	546	148	.345	.361	.235	.027
Odds	5:1	4:1	4:1	1:1	5:1	3:1	29:1	1:1
x41	2397	−101	−229	1650	.678	−.046	.005	.566
Odds	603:1	1:1	2:1	26:1	807:1	2:1	<1:1	74:1
x42	1596	1906	−67	−6	.430	.603	.062	.071
Odds	73:1	41:1	1:1	<1:1	42:1	32:1	2:1	1:1
x44	1825	2074	1414	−909	.450	.731	.661	−.251
Odds	7:1	12:1	74:1	8:1	5:1	21:1	2064:1	5:1
First year after clover								
x40	1099	1879	1541	849	.377	.636	.695	.310
Odds	13:1	10:1	29:1	5:1	9:1	11:1	25:1	5:1
x41	1915	1835	1592	1200	.741	.742	.547	.544
Odds	40:1	79:1	22:1	21:1	23:1	124:1	21:1	26:1
x42	2198	1172	1980	448	.809	.687	.735	.231
Odds	79:1	10:1	6:1	5:1	47:1	22:1	6:1	9:1
x44	1774	2408	1346	586	.752	.955	.523	.212
Odds	20:1	14:1	14:1	9:1	22:1	24:1	27:1	6:1
Second year after clover								
x40	1086	1930	2399	1960	.360	.716	.912	.672
Odds	13:1	27:1	38:1	3332:1	26:1	77:1	55:1	2499:1
x41	1424	2546	2784	1636	.584	1.060	1.027	.608
Odds	96:1	16:1	45:1	78:1	100:1	24:1	108:1	158:1
x42	1818	2298	1949	1677	.716	1.081	.725	.659
Odds	18:1	18:1	40:1	42:1	85:1	29:1	90:1	237:1
x44	3000	3051	1566	835	1.052	1.171	.718	.427
Odds	68:1	36:1	48:1	55:1	134:1	39:1	46:1	39:1

creases where the amount did not exceed 50 pounds sodium nitrate per acre. However, in Set *x22*, 100 pounds nitrate per acre gave the largest increases.

(3) K_2O 100 pounds per acre constant (Table 6). In the three sets of treatments considered here, the largest increases occurred with Treatments 414, 224, and 144, and the odds were large enough to be significant. It cannot be said, however, that nitrate exhibited a general tendency to increase yields further as successively larger applications were made.

(4) P_2O_5 32 pounds per acre constant (Table 7). In Set *x*11 nitrate gave successively greater increases in relation to the amount applied. In Set *x*12, however, the largest and most significant increase was secured with Treatment 112. In Set *x*14 the maximum increase due to nitrogen was in Treatment 414.

(5) P_2O_5 64 pounds per acre constant (Table 8). In Set *x*21 the largest and most significant increase resulted from Treatment 121. In Set *x*22 nitrate gave successively larger increases as far as Treatment 222. In Set *x*24, however, the weights showed no definite trend, Treatment 224 producing the only increase that was larger than that produced by Treatment 024. On the basis of increase in number of ears there was a definite trend upward as far as Treatment 224.

(6) P_2O_5 128 pounds per acre constant (Table 9). The increases in number of ears in Set *x*41 became successively larger as far as Treatment 241, but with respect to weights, Treatment 141 was the maximum. In the two other sets Treatments 142 and 144 produced respectively the largest increases.

In the foregoing "complete" fertilizer combinations, nitrate gave large but inconsistent increases in yields. Its addition, in increasing amounts, to various constants of phosphorus and potash, with no clover in the rotation, gave highly variable responses. On the other hand, applied the first year after clover in identical combinations, it gave very definite responses on many plots. The quantity of phosphorus used in the combination appeared to have considerable influence upon the size of the increases resulting from the nitrate. These increases were smallest and the odds least significant where 32 pounds P_2O_5 per acre was applied. In the second year after clover nitrate gave much larger increases where the applications of potash did not exceed 25 to 50 pounds K_2O per acre. Here again nitrate responded least where the basal treatment of phosphorus was lowest. In general, side dressings of 7.5 to 15 pounds of nitrogen per acre gave increases larger than those resulting from the heaviest applications of 30 pounds.

Ordinarily one would expect nitrate to be more effective on soils in which this element is depleted than on fertile soils, and to be less effective during the first and second years after clover than when no clover at all has been used. For example, in these experiments best results with nitrate would be expected with no clover in the rotation on Field 1300, which the average yields of the check plots (means of average yields given in Table 10) show to have been greatly depleted in fertility before clover was used; and least results would be expected on the fairly fertile soil of Fields 800, 900, and 1000 (Table 10) during the first year after clover. The actual results, however, were contrary to expectations: nitrates proved most effective following clover in the rotation.

TABLE 10.—AVERAGE YIELDS OF CHECK PLOTS IN DIFFERENT FIELDS, BY YEARS, SHOWING EFFECT OF CLOVER IN ROTATION

Field	Year	Position in rotation	Marketable ears		Tons fodder per acre
			Number per acre	Tons per acre	
800	1923	No clover in rotation.....	8 809	2.54	3.94
1000	1923	First year after sod.....	8 728	2.94	3.88
1000	1924	Second year after sod.....	8 061	2.73	3.19
1300	1924	No clover in rotation.....	3 960	1.09	1.62
900	1925	First year after clover.....	8 203	2.56	5.41
1300	1925	No clover in rotation.....	2 505	.68	1.82
800	1926	First year after clover.....	7 536	2.44	3.68
900	1926	Second year after clover....	5 819	1.78	4.66
800	1927	Second year after clover....	7 092	2.28	2.58
1000	1927	First year after clover.....	6 708	2.21	2.85
1000	1928	Second year after clover....	4 061	1.15	2.96
1300	1928	First year after clover.....	4 202	1.14	2.05

From the data representing results obtained by side-dressing sodium nitrate as part of a complete fertilizer, (summarized as means in Sections B, C, and D of Tables 11, 12, and 13), it is evident that the smallest nitrate treatment (50 pounds per acre; i.e., 7.5 pounds of nitrogen per acre) gave larger and more consistent increases in yields than the heavier dosages. It is apparent, also, that the percentages of increase depended to a considerable extent upon the amounts and proportions of minerals which were used as a basal treatment.

Analysis of Relative Nitrogen Efficiency in Different Combinations

The preceding discussion concerning the effects of side-dressing sodium nitrate is useful in defining some of the limitations in the use of this salt. Considerable doubt still remains, however, concerning the specific quantities of sodium nitrate, and the proper basal treatment of accompanying minerals, which should be used to give the best results. Determination and analysis of the relative efficiencies of the various fertilizer elements in the different combinations used here will aid in answering these questions.

Efficiency of Nitrogen When Used With Phosphorus.—The relations existing between nitrogen and phosphorus are shown in Tables 14, 15, and 16. The data in Table 14 reveal that the efficiency of nitrogen used with phosphorus was not only very low in general but significantly negative in several instances. The greatest efficiency of nitrogen occurred in Sets 12*x*, 22*x*, and 42*x*, of which Sets 12*x* and

TABLE 11.—MEAN PERCENTAGE INCREASES IN NUMBER OF MARKETABLE EARS DUE TO VARIOUS FERTILIZER TREATMENTS

NITROGEN SERIES

Potash increasing	(A) Nitrogen increasing			
	00x	10x	20x	40x
x00	.....	5.10	−2.99	−5.27
x01	−8.32*	−15.32	−7.57	13.37*
x02	− .12	1.90	−4.28	−1.07
x04	2.44	−2.06	4.03	−1.31

Phosphorus increasing	(B) Nitrogen increasing			
	0x1	1x1	2x1	4x1
x01	−8.32*	−15.32	−7.57	13.37*
x11	15.14*	10.49*	14.32*	12.96
x21	16.39*	32.66*	27.23*	19.48*
x41	32.76*	24.15*	22.28*	20.37*

Phosphorus increasing	(C) Nitrogen increasing			
	0x2	1x2	2x2	4x2
x02	− .12	1.90	−4.28	−1.07
x12	17.94*	30.61*	28.98*	10.62*
x22	21.34*	41.66*	24.18*	31.07*
x42	32.83*	26.32*	21.03*	9.45*

Phosphorus increasing	(D) Nitrogen increasing			
	0x4	1x4	2x4	4x4
x04	2.44	−2.06	4.03	−1.31
x14	26.98*	34.32*	23.79*	25.42*
x24	17.22*	34.70*	13.25	33.54*
x44	38.07*	44.22*	19.34*	3.21*

Phosphorus increasing	(E) Nitrogen increasing			
	0x0	1x0	2x0	4x0
x00	.....	5.10	−2.99	−5.27
x10	24.37*	12.31*	2.06	13.80
x20	10.72	28.22*	26.76*	32.34*
x40	18.99*	28.40*	22.64*	14.59*

Potash increasing	(F) Nitrogen increasing			
	01x	11x	21x	41x
x10	24.37*	12.31*	2.06	13.80
x11	15.14*	10.49*	14.32*	12.96
x12	17.94*	30.61*	28.98*	10.62*
x14	26.98*	34.32*	23.79*	25.42*

Potash increasing	(G) Nitrogen increasing			
	02x	12x	22x	42x
x20	10.72	28.22*	26.76*	32.34*
x21	16.39*	32.66*	27.23*	19.48*
x22	21.34*	41.66*	24.18*	31.07*
x24	17.22*	34.70*	13.25	33.54*

Potash increasing	(H) Nitrogen increasing			
	04x	14x	24x	44x
x40	18.99*	28.40*	22.64*	14.59*
x41	32.76*	24.15*	22.28*	20.37*
x42	32.83*	26.32*	21.03*	9.45*
x44	38.07*	44.22*	19.34*	3.21

PHOSPHORUS SERIES

Potash increasing	(I) Phosphorus increasing			
	00x	01x	02x	04x
0x0	.....	24.37*	10.72	18.99*
0x1	−8.32*	15.14*	16.39*	32.76*
0x2	− .12	17.94*	21.34*	32.83*
0x4	2.44	26.98*	17.22*	38.07*

Potash increasing	(J) Phosphorus increasing			
	10x	11x	12x	14x
1x0	5.10	12.31*	28.22*	28.40*
1x1	−15.32	10.49*	32.66*	24.15*
1x2	1.90	30.61*	41.66*	26.32*
1x4	−2.06	34.32*	34.70*	44.22*

Potash increasing	(K) Phosphorus increasing			
	20x	21x	22x	24x
2x0	−2.99	2.06	26.76*	22.64*
2x1	−7.57	14.32*	27.23*	22.28*
2x2	−4.28	28.98*	24.18*	21.03*
2x4	4.03	23.79*	13.25	19.34*

Potash increasing	(L) Phosphorus increasing			
	40x	41x	42x	44x
4x0	−5.27	13.80	32.34*	14.59*
4x1	13.37*	12.96	19.48	20.37*
4x2	−1.07	10.62*	31.07*	9.45*
4x4	−1.31	25.42*	33.54*	3.21

*Statistically significant, odds of over 30:1, according to Table 39, Appendix.

TABLE 12.—MEAN PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS DUE TO VARIOUS FERTILIZER TREATMENTS

NITROGEN SERIES

Potash increasing	(A) Nitrogen increasing			
	00x	10x	20x	40x
x00	.....	5.51	−2.91	−4.85
x01	−8.98*	−12.41	−7.17*	17.38*
x02	1.63	1.89	−2.91	−3.01
x04	3.58	−4.70	5.32	−2.24

Phosphorus increasing	(B) Nitrogen increasing			
	0x1	1x1	2x1	4x1
x01	−8.98*	−12.41	−7.17*	17.38*
x11	13.91*	9.07	14.45	16.06
x21	18.75*	34.47*	31.92*	22.35*
x41	37.41*	32.76*	26.20*	24.94*

Phosphorus increasing	(C) Nitrogen increasing			
	0x2	1x2	2x2	4x2
x02	1.63	1.89	−2.91	−3.01
x12	17.99*	34.73*	31.95*	12.14*
x22	18.52*	44.47*	29.93*	32.04*
x42	37.28*	40.11*	25.66*	13.13*

Phosphorus increasing	(D) Nitrogen increasing			
	0x4	1x4	2x4	4x4
x04	3.58	−4.70	5.32	−2.24
x14	27.62*	38.54*	25.10*	30.12*
x24	21.36*	31.11*	16.50	35.53*
x44	43.50*	55.58*	27.27*	5.89

Phosphorus increasing	(E) Nitrogen increasing			
	0x0	1x0	2x0	4x0
x00	.....	5.51	−2.91	−4.85
x10	22.63*	12.62*	4.96	14.81
x20	10.02*	28.93*	31.50*	38.98*
x40	19.45*	30.12*	29.16*	15.73*

Potash increasing	(F) Nitrogen increasing			
	01x	11x	21x	41x
x10	22.63*	12.62*	4.96	14.81
x11	13.91*	9.07	14.45	16.06
x12	17.99*	34.73*	31.95*	12.14*
x14	27.62*	38.54*	25.10*	30.12*

Potash increasing	(G) Nitrogen increasing			
	02x	12x	22x	42x
x20	10.02*	28.93*	31.50*	38.98*
x21	18.75*	34.47*	31.92*	22.35*
x22	18.52*	44.47*	29.93*	32.04*
x24	21.36*	31.11*	16.50	35.53*

Potash increasing	(H) Nitrogen increasing			
	04x	14x	24x	44x
x40	19.45*	30.12*	29.16*	15.73*
x41	37.41*	32.76*	26.20*	24.94*
x42	37.28*	40.11*	25.66*	13.13*
x44	43.50*	55.58*	27.27*	5.89

PHOSPHORUS SERIES

Potash increasing	(I) Phosphorus increasing			
	00x	01x	02x	04x
0x0	.....	22.63*	10.02*	19.45*
0x1	−8.98*	13.91*	18.75*	37.41*
0x2	1.63	17.99*	18.52*	37.28*
0x4	3.58	27.62*	21.36*	43.50*

Potash increasing	(J) Phosphorus increasing			
	10x	11x	12x	14x
1x0	5.51	12.62*	28.93*	30.12*
1x1	−12.41	9.07	34.47*	32.76*
1x2	1.89	34.73*	44.47*	40.11*
1x4	−4.70	38.54*	31.11*	55.58*

Potash increasing	(K) Phosphorus increasing			
	20x	21x	22x	24x
2x0	−2.91	4.96	31.50*	29.16*
2x1	−7.17*	14.45	31.92*	26.20*
2x2	−2.91	31.95*	29.93*	25.66*
2x4	5.32	25.10*	16.50	27.27*

Potash increasing	(L) Phosphorus increasing			
	40x	41x	42x	44x
4x0	−4.85	14.81	38.98*	15.73*
4x1	17.38*	16.06	22.35*	24.94*
4x2	−3.01	12.14*	32.04*	13.13*
4x4	−2.24	30.12*	35.53*	5.89

*Statistically significant, odds over 30:1 according to Table 39, Appendix.

TABLE 13.—MEAN PERCENTAGE INCREASES IN WEIGHTS OF GREEN FODDER DUE TO VARIOUS FERTILIZER TREATMENTS

NITROGEN SERIES

Potash increasing	(A) Nitrogen increasing			
	00x	10x	20x	40x
x00	.....	9.74	−4.86	−1.58
x01	−12.24	2.09	−5.25	16.63*
x02	5.07	28.22*	−0.20	6.26
x04	−2.44	7.70	24.66*	−2.37

Phosphorus increasing	(B) Nitrogen increasing			
	0x1	1x1	2x1	4x1
x01	−12.24	2.09	−5.25	16.63*
x11	10.97	−1.77	10.04*	18.05*
x21	23.18*	26.66*	27.78*	13.65
x41	32.29*	35.46*	33.20*	34.85*

Phosphorus increasing	(C) Nitrogen increasing			
	0x2	1x2	2x2	4x2
x02	5.07	28.22*	− .20	6.26
x12	13.58	42.34*	19.79	19.45*
x22	25.62*	34.30*	38.69*	35.15*
x42	33.02*	48.45*	40.71*	21.74*

Phosphorus increasing	(D) Nitrogen increasing			
	0x4	1x4	2x4	4x4
x04	−2.44	7.70	24.66*	−2.37
x14	39.36*	35.91*	29.81*	29.89*
x24	33.74*	36.24*	42.88*	40.80*
x44	47.62*	68.36*	52.05*	19.01*

Phosphorus increasing	(E) Nitrogen increasing			
	0x0	1x0	2x0	4x0
x00	.....	9.74	−4.86	−1.58
x10	15.64*	14.71*	1.01	−1.55
x20	11.46	13.91*	7.74	31.56*
x40	1.26	23.09*	38.06*	26.32*

Potash increasing	(F) Nitrogen increasing			
	01x	11x	21x	41x
x10	15.64*	14.71*	1.01	−1.55
x11	10.97	−1.77	10.04*	18.05*
x12	13.58	42.34*	19.79	19.45*
x14	39.36*	35.91*	29.81*	29.89*

Potash increasing	(G) Nitrogen increasing			
	02x	12x	22x	42x
x20	11.46	13.91*	7.74	31.56*
x21	23.18*	26.66*	27.78*	13.65
x22	25.62*	34.30*	38.69*	35.15*
x24	33.74*	36.24*	42.88*	40.80*

Potash increasing	(H) Nitrogen increasing			
	04x	14x	24x	44x
x40	1.26	23.09*	38.06*	26.32*
x41	32.29*	35.46*	33.20*	34.85*
x42	33.02*	48.45*	40.71*	21.74*
x44	47.62*	68.36*	52.05*	19.01*

PHOSPHORUS SERIES

Potash increasing	(I) Phosphorus increasing			
	00x	01x	02x	04x
0x0	.....	15.64*	11.46	1.26
0x1	−12.24	10.97	23.18*	32.29*
0x2	5.07	13.58	25.62*	33.02*
0x4	−2.44	39.36*	33.74*	47.62*

Potash increasing	(J) Phosphorus increasing			
	10x	11x	12x	14x
1x0	9.74	14.71	13.91*	23.09*
1x1	2.09	−1.77	26.66*	35.46*
1x2	28.22*	42.34*	34.30*	48.45*
1x4	7.70	35.91*	36.24*	68.36*

Potash increasing	(K) Phosphorus increasing			
	20x	21x	22x	24x
2x0	−4.86	1.01	7.74	38.06*
2x1	−5.25	10.04*	27.78*	33.20*
2x2	− .20	19.79	38.69*	40.71*
2x4	24.66*	29.81*	42.88*	52.05*

Potash increasing	(L) Phosphorus increasing			
	40x	41x	42x	44x
4x0	−1.58	−1.55	31.56*	26.32*
4x1	16.63*	18.05*	13.65	34.85*
4x2	6.26	19.45*	35.15*	21.74*
4x4	−2.37	29.89*	40.80*	19.01*

*Statistically significant, odds over 30:1 according to Table 39, Appendix.

TABLE 14.—EFFECT OF PHOSPHORUS ON NITROGEN EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean nitrogen efficiency	Set	Mean nitrogen efficiency	Set	Mean nitrogen efficiency
	perct.		*perct.*		*perct.*
10*x*.....	−1.48 ± 2.8	20*x*.....	−.98 ± 2.3	40*x*.....	2.76 ± 2.8
11*x*.....	3.20 ± 3.2	21*x*.....	−1.42 ± 3.7	41*x*.....	−2.26 ± 3.6
12*x*.....	17.58 ± 3.4	22*x*.....	10.30 ± 3.2	42*x*.....	15.06 ± 3.0
14*x*.....	5.23 ± 4.1	24*x*.....	−7.34 ± 3.6	44*x*.....	−19.49 ± 3.0

[a]See Table 40, Appendix, for detail data.

42*x* showed significant increases and Set 22*x* very nearly so. In other words, the efficiency of nitrogen with phosphorus was uniformly low except where 64 pounds P_2O_5 per acre was applied basally.

This dominance of the 64-pound P_2O_5 dosage in increasing the efficiency of nitrogen in nitrogen-phosphorus combinations is further indicated by comparison of the modes in Table 15; Treatments 122, 220, and 420 are the highest in their respective groups. These results should not be stressed too greatly, however, because Treatments 220, 420, and 401 are the only ones statistically significant.

Comparison of the treatments giving the maximum increases in yields (Table 16) shows that when all three elements were used, the single nitrogen treatment gave better yields than heavier applications. Treatments 144, 212, and 420 gave the largest increases in their respective groups. These results, which are only partially in agreement with the data in Tables 14 and 15, serve to show that mere yield increases over checks without further comparisons of interrelationships cannot be relied upon for adequate interpretation of experimental results such as these.

Thus two important points regarding the relation between nitrogen and phosphorus are indicated by the data in Tables 14, 15, and 16,

TABLE 15.—EFFECT OF PHOSPHORUS ON NITROGEN EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN NITROGEN EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Nitrogen efficiency	Treatment	Nitrogen efficiency	Treatment	Nitrogen efficiency
	perct.		*perct.*		*perct.*
100.....	5.51 ± 5.0	201.....	1.81 ± 3.2	401.....	26.36 ± 4.3
112.....	16.74 ± 7.3	212.....	13.96 ± 8.0	414.....	2.50 ± 8.8
122.....	25.95 ± 9.3	220.....	21.48 ± 5.5	420.....	28.96 ± 5.2
144.....	12.08 ± 10.1	240.....	9.71 ± 5.7	440.....	−3.72 ± 5.6

[a]See Table 40, Appendix, for detail data.

TABLE 16.—EFFECT OF PHOSPHORUS ON NITROGEN AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, A	100.....	5.51 ± 5.0	204.....	5.32 ± 5.9	401.....	17.38 ± 3.3
12, F	114.....	38.54 ± 5.1	212.....	31.95 ± 6.3	414.....	30.12 ± 7.0
12, G	122.....	44.47 ± 8.1	221.....	31.92 ± 5.2[a]	420.....	38.98 ± 4.4
12, H	144.....	55.58 ± 7.7	240.....	29.16 ± 4.1	441.....	24.94 ± 2.7

[a]Treatment 220 had an efficiency of 31.50 ± 4.8 percent.

namely: (1) that the maximum efficiency of nitrogen is associated with the smallest dosage; and (2) that an optimum application of phosphorus increases nitrogen efficiency to an appreciable extent.

No definite reason can be advanced, as a result of these experiments, for the relations between nitrogen and phosphorus which have been recorded. MacTaggart,[36*] in a study of Canada field peas, soybeans, and alfalfa, found that altho total dry matter and total nitrogen were greatly increased by added phosphorus, the percentage of nitrogen was influenced to a less extent. Phosphorus applied in combination with nitrogen, potash, and sulfur acted in practically the same manner. Blair and Prince,[7*] who worked with field corn, reached somewhat similar conclusions, showing that the percentage of nitrogen in the dry matter was not influenced by the amount of phosphoric acid used. However, in later work with rape and buckwheat these investigators[8*] noted a slight increase in nitrogen recovery associated with increases in the amount of phosphoric acid. Breazeale[11*] observed that the absorption of nitrogen by wheat seedlings in culture solutions, as determined by dry weight and total nitrogen, was not influenced materially by varying amounts of potash, phosphoric acid, and gypsum.

There is no consistent evidence, from the literature reviewed, that phosphorus has any appreciable effect in increasing the availability of nitrogen. A tendency in that direction appears to be indicated in Table 14, but there are no supporting chemical analyses from these experiments available as proof.

Efficiency of Nitrogen When Used With Potash.—In the brief discussion of the relations existing between nitrogen and potassium (page 373) the statement was made that the results were highly variable and the relationships difficult to define. These relations are given in summary form in Tables 17, 18, and 19.

TABLE 17.—EFFECT OF POTASH ON NITROGEN EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean nitrogen efficiency	Set	Mean nitrogen efficiency	Set	Mean nitrogen efficiency
	perct.		*perct.*		*perct.*
1x0	6.27 ± 2.8	2x0	2.65 ± 2.7	4x0	3.14 ± 2.6
1x1	.70 ± 3.4	2x1	1.08 ± 3.0	4x1	4.91 ± 3.2
1x2	11.44 ± 3.7	2x2	2.30 ± 3.6	4x2	5.28 ± 2.7
1x4	6.12 ± 3.7	2x4	−5.47 ± 3.5	4x4	−6.69 ± 3.3

[a]See Table 40, Appendix, for detail data.

The probable errors in connection with the efficiency factors given in Table 17 are so large, with the exception of that for Set 1x2, that the factors have little or no real meaning. As shown by a comparison of the modes (Table 18), potash had a relatively slight tendency to increase nitrogen efficiency where the single dosage of nitrogen was used. Treatment 122, with the single dosage of nitrogen, had the highest nitrogen efficiency but the efficiency factor was not statistically significant. Among the treatments having the double dosage of nitrogen, Treatment 220 was the most efficient. Successive additions of potash caused a decrease in nitrogen efficiency. This was also true where the quadruple dosage of nitrogen was constant. Altho the results were very inconclusive, Table 18 indicates that where 15 or 30 pounds of nitrogen per acre was used, the omission of potash was essential to secure the greatest efficiency of nitrogen. On the other hand, when 7.5 pounds of nitrogen was used, dosages of potash up to 50 pounds of K_2O per acre sometimes gave slight increases in nitrogen efficiency. These relations between nitrogen and potash are further indicated in Table 19, where it is shown that it was only when nitrogen was not applied in excess of 7.5 pounds per acre that the yields increased in relation to increases in potash dosages. When 15 or 30 pounds of nitrogen per acre was applied, yields tended to remain static.

TABLE 18.—EFFECT OF POTASH ON NITROGEN EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN NITROGEN EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Nitrogen efficiency	Treatment	Nitrogen efficiency	Treatment	Nitrogen efficiency
	perct.		*perct.*		*perct.*
120	18.91 ± 4.7	220	21.48 ± 5.5	420	28.96 ± 5.2
121	15.72 ± 6.4	221	13.17 ± 6.7	401	26.36 ± 4.3
122	25.95 ± 9.3	212	13.96 ± 8.0	422	13.52 ± 5.6
144	12.08 ± 10.1	204	1.74 ± 6.7	424	14.17 ± 4.2

[a]See Table 40, Appendix, for detail data.

The important points brought out in Tables 17, 18, and 19 are therefore:

(1) The most efficient fertilizer combination for sweet corn in these tests was Set 1x2 (Table 17), and in this set the most efficient treatment was No. 122 (Table 18).

(2) Potash applied in combination with double and quadruple nitrogen dosages tended to reduce nitrogen efficiency.

TABLE 19.—EFFECT OF POTASH ON NITROGEN AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, E	140.....	30.12 ± 6.1	220.....	31.50 ± 4.8	420.....	38.98 ± 4.4
12, B	121.....	34.47 ± 4.7	221.....	31.92 ± 5.2	441.....	24.94 ± 2.7[b]
12, C	122.....	44.47 ± 8.1	212.....	31.95 ± 6.3	422.....	32.04 ± 3.2
12, D	144.....	55.58 ± 7.7	244.....	27.27 ± 3.1[a]	424.....	35.53 ± 2.5

[a]Treatment 214 had an efficiency of 25.10 ± 5.2 percent.
[b]Treatment 421 had an efficiency of 22.35 ± 7.0 percent.

Accordingly, if one expects side-dressed nitrate to give good results, 50 pounds of sodium nitrate per acre is the maximum application, provided not more than 50 pounds of K_2O per acre is used as part of the basal treatment. If phosphorus is used alone as the basal mineral, side-dressing quantities of sodium nitrate in excess of 50 pounds per acre would be permissible.

EFFECTS OF PHOSPHORUS

As stated before, phosphorus was probably the limiting factor in the soils used in these experiments. Unfortunately, during the early years of these experiments qualitative field tests for available phosphorus, such as Bray's[9]* and Spurway's,[47]* were not available, and there was consequently no reasonably inexpensive way of finding out how the available phosphorus in these plots checked against that of the soils upon which sweet corn is usually grown elsewhere.

Phosphorus Alone

In view of the probable deficiency of available phosphorus in the soils of these plots, the heavier dosages of phosphorus were expected to give the larger and more consistent increases in yield. The results, however, were contrary to expectation, as shown below.

With no clover in the rotation, the largest increase was obtained

by adding 64 pounds P_2O_5 per acre, but the odds show that this was nothing more than a tendency (Table 20). The odds for the smaller increases obtained with 32 pounds P_2O_5 per acre approach certainty as a limit. During the first and also during the second years after clover, the largest increases occurred with 32 pounds per acre, but the odds were not significant. The means of all plots receiving phosphorus alone, and including all positions in the rotation, show that Treatment

TABLE 20.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SUPERPHOSPHATE AND POTASSIUM CHLORID
(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Phosphorus series							
	00x	01x	02x	04x	00x	01x	02x	04x
	Number of ears				Tons marketable ears			
No clover in rotation								
0x0	....	1017	1765	1239	....	.296	.370	.345
Odds	....	70:1	12:1	5:1	....	56:1	10:1	5:1
0x1	−290	323	2835	2397	−.097	.074	.869	.678
Odds	3:1	2:1	10:1	603:1	4:1	2:1	16:1	807:1
0x2	34	2108	1057	1596	.014	.573	.022	.430
Odds	2:1	23:1	65:1	73:1	2:1	24:1	1:1	42:1
0x4	168	1172	646	1825	.021	.236	.209	.450
Odds	3:1	10:1	7:1	7:1	1:1	5:1	5:1	5:1
First year after clover								
0x0	....	1491	444	1099	....	.448	.118	.377
Odds	....	3:1	2:1	13:1	....	12:1	3:1	9:1
0x1	−941	1321	760	1915	−.336	.425	.292	.741
Odds	37:1	45:1	4:1	40:1	24:1	61:1	6:1	23:1
0x2	101	145	1685	2198	.030	.061	.530	.809
Odds	2:1	1:1	14:1	79:1	2:1	1:1	10:1	47:1
0x4	646	1204	1103	1774	.251	.439	.445	.752
Odds	38:1	45:1	31:1	20:1	160:1	41:1	27:1	22:1
Second year after clover								
0x0	....	1561	369	1086	....	.422	.248	.360
Odds	....	7:1	4:1	13:1	....	9:1	19:1	26:1
0x1	−314	708	359	1424	−.086	.145	.242	.584
Odds	3:1	5:1	4:1	96:1	2:1	3:1	11:1	100:1
0x2	−172	1450	1531	1818	.043	.510	.548	.716
Odds	2:1	22:1	48:1	18:1	2:1	11:1	63:1	85:1
0x4	−495	2450	1697	3000	−.130	.832	.658	1.052
Odds	3:1	15:1	25:1	68:1	2:1	15:1	39:1	134:1

010 gave the largest increases and had significant odds (Section I, Tables 11 and 12). Similar effects of phosphorus have been noted by Schuster,[43*] Comin and Bushnell,[15*] Blackwell and Buie,[6*] and others.

Phosphorus Increasing, Nitrogen Constant

Much larger and more uniform increases in yields were obtained from the use of combinations of nitrogen and phosphorus than from applications of phosphorus alone (Table 2).

With no clover in the rotation, yields increased (except those from Treatment 210) as applications of phosphorus were increased up to but not including the quadruple dosage. During both the first and second years after clover, sweet-corn yields again increased when larger amounts of phosphorus were applied. The increases were larger than when no clover was in the rotation, and the maximum was apparently beyond 128 pounds P_2O_5 per acre. The only exception was Treatment 440, the results from which indicated that with a quadruple dosage of nitrogen constant, the maximum increase for phosphorus had been passed so far as weight of marketable ears was concerned.

The means of the plots receiving nitrogen-phosphorus combinations, including all such plots in all positions in the rotation (Section E, Tables 11 and 12) show that altho the response of sweet corn to these fertilizer treatments as indicated by number of ears and weight of ears was not quite the same, the maximum increases were obtained for both numbers of ears and weights of ears when 64 pounds of P_2O_5 per acre was applied (except Treatment 140, which gave the largest increases in Set 1x0).

Phosphorus Increasing, Potash Constant

Combinations of phosphorus and potash gave much better results than phosphorus applied alone. In general the yield increased in relation to successive increments of phosphorus (Table 20). With no clover in the rotation, all these combinations gave increased yields over the checks, and the largest increases were obtained in Set 0x1. During the first year after clover the highest and most consistent increases were obtained with Set 0x2, in which the largest increases occurred with the largest dosages of phosphorus. Set 0x1 gave large increases but they were not quite consistent, Treatment 021 being somewhat out of line with Treatments 011 and 041. The increases in Set 0x4 were slightly smaller, but were also (except in regard to number of ears) related to the amount of phosphorus added. During the second year after clover the yields on the basis of weight increased

in relation to the amount of phosphorus in the combination, except with Treatment 024 in Set 0*x*4, where a slight discrepancy occurred.

The means of the plots receiving applications of phosphorus-potash fertilizers, including all such plots in all positions in the rotation, show that in regard to both number and weight of marketable ears increases became successively larger in relation to the phosphorus dosage, except in one treatment, No. 024 (Section I, Tables 11 and 12).

Phosphorus Increasing, Nitrogen and Potash Constant

The fertilizer analyses discussed herein are "complete" analyses having different constants of nitrogen and potash with phosphorus varying. Each of the six comparisons at each position in the rotation involves 16 treatment combinations.

No Clover in Rotation.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). In general, both in number and in weight of ears, increases were successively larger in relation to increased amounts of phosphorus in Sets 1*x*1, 1*x*2, and 1*x*4. Exceptions to this trend occurred in Treatments 141 and 124.

(2) Nitrogen 15 pounds per acre constant (Table 22). Yield increases due to phosphorus were very much less uniform than with 7.5 pounds nitrogen constant. The maximum increase in Set 2*x*1 occurred at Treatment 221, Treatment 241 giving no increase over the check. In Set 2*x*2 only Treatment 212, and in Set 2*x*4 only Treatment 244 gave significantly large increases.

(3) Nitrogen 30 pounds per acre constant (Table 23). Phosphorus gave very erratic increases. There was considerable uniformity, however, in the trend of results in Set 4*x*4, the increases becoming greater in relation to the dosage of phosphorus except in Treatment 444.

(4) K_2O 25 pounds per acre constant (Table 4). When the smaller dosages of nitrogen were constant (Sets 1*x*1 and 2*x*1), increasing applications of phosphorus gave successively larger increases in yield, except in Treatments 141 and 241. On the other hand, phosphorus was ineffective with a high nitrogen constant (Set 4*x*1) except in Treatment 441.

(5) K_2O 50 pounds per acre constant (Table 5). Increases in yield became successively greater in relation to phosphorus dosages only in Set 1*x*2. Elsewhere the effects of phosphorus were somewhat erratic.

(6) K_2O 100 pounds per acre constant (Table 6). Successively larger increases in yield occurred with increased dosages of phosphorus in Set 1*x*4 except with Treatment 124, and in Set 4*x*4 except with Treatment 444. Treatment 244 was the only one in Set 2*x*4 giving a substantial increase in yield.

First Year After Clover.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). The tendency for yields to increase in relation to the size of the phosphorus dosage was very marked. In but one instance (Treatment 142) was there any evidence that the maximum increase in yield had been passed.

TABLE 21.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SUPERPHOSPHATE AND POTASSIUM CHLORID WITH A SINGLE DOSAGE OF SODIUM NITRATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Phosphorus series							
	10x	11x	12x	14x	10x	11x	12x	14x
	Number of ears				Tons marketable ears			
No clover in rotation								
1x0	613	849	1805	1327	.136	.195	.391	.361
Odds	23:1	21:1	46:1	4:1	15:1	11:1	16:1	3:1
1x1	−889	566	1165	−101	−.300	.176	.337	−.046
Odds	4:1	23:1	7:1	1:1	4:1	24:1	12:1	2:1
1x2	−667	727	1421	1906	−.458	.255	.397	.603
Odds	11:1	11:1	27:1	41:1	5:1	15:1	3:1	32:1
1x4	236	2222	1185	2074	.022	.636	.381	.731
Odds	2:1	7:1	8:1	12:1	2:1	18:1	17:1	21:1
First year after clover								
1x0	−186	731	1334	1879	−.060	.246	.490	.636
Odds	2:1	61:1	22:1	10:1	2:1	30:1	17:1	11:1
1x1	−634	824	1636	1835	−.197	.175	.527	.742
Odds	2:1	16:1	28:1	79:1	2:1	3:1	48:1	124:1
1x2	356	1754	2768	1172	.181	.622	.927	.687
Odds	3:1	51:1	45:1	10:1	4:1	25:1	37:1	22:1
1x4	−768	1394	2388	2408	−.354	.496	.680	.955
Odds	12:1	44:1	24:1	14:1	28:1	28:1	20:1	24:1
Second year after clover								
1x0	566	748	1808	1930	.234	.270	.673	.716
Odds	3:1	5:1	72:1	27:1	3:1	5:1	253:1	77:1
1x1	−1379	520	2667	2546	−.224	.182	.968	1.060
Odds	5:1	304:1	43:1	16:1	3:1	19:1	58:1	24:1
1x2	424	2465	2430	2298	.229	.827	.872	1.081
Odds	4:1	46:1	14:1	18:1	5:1	48:1	9:1	29:1
1x4	399	1884	1848	3051	.144	.740	.460	1.171
Odds	2:1	24:1	13:1	36:1	2:1	30:1	34:1	39:1

(2) Nitrogen 15 pounds per acre constant (Table 22). The trend was similar to that where 7.5 pounds of nitrogen was constant. Treatment 241 showed evidence of having passed the maximum increase in yield, and in Set 2x4, Treatment 214 gave increases only slightly less than Treatment 244.

(3) Nitrogen 30 pounds per acre constant (Table 23). Phosphorus showed very little tendency to increase yields materially in combinations containing the low potash dosage (Set 4x1), but was more effective in

TABLE 22.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SUPERPHOSPHATE AND POTASSIUM CHLORID WITH A DOUBLE DOSAGE OF SODIUM NITRATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Phosphorus series							
	20x	21x	22x	24x	20x	21x	22x	24x
	Number of ears				Tons marketable ears			
No clover in rotation								
2x0	−192	−1152	1380	546	−.092	−.359	.467	.235
Odds	1:1	12:1	29:1	4:1	2:1	13:1	27:1	29:1
2x1	596	903	1253	−229	.071	.290	.382	.005
Odds	3:1	6:1	603:1	2:1	2:1	18:1	57:1	<1:1
2x2	188	1529	491	−67	.039	.395	.178	.062
Odds	1:1	806:1	3:1	1:1	4:1	59:1	4:1	2:1
2x4	−1044	876	−1010	1414	−.399	.157	−.357	.661
Odds	2:1	13:1	18:1	74:1	215:1	11:1	17:1	2064:1
First year after clover								
2x0	28	457	1540	1541	−.032	.283	.564	.695
Odds	<1:1	2:1	19:1	29:1	1:1	4:1	17:1	25:1
2x1	−857	792	1657	1592	−.264	.201	.601	.547
Odds	31:1	4:1	46:1	22:1	66:1	2:1	30:1	21:1
2x2	−877	1418	1152	1980	−.302	.565	.527	.735
Odds	6:1	14:1	19:1	6:1	6:1	15:1	30:1	6:1
2x4	731	1289	667	1346	.287	.479	.379	.523
Odds	3:1	8:1	4:1	14:1	6:1	9:1	5:1	27:1
Second year after clover								
2x0	−414	662	1596	2399	−.056	.189	.552	.912
Odds	3:1	4:1	13:1	38:1	2:1	3:1	24:1	55:1
2x1	−591	838	2030	2784	−.108	.325	.742	1.027
Odds	30:1	61:1	11:1	45:1	12:1	34:1	13:1	108:1
2x2	197	1868	2864	1949	.187	.632	1.000	.725
Odds	1:1	9:1	49:1	40:1	5:1	9:1	46:1	90:1
2x4	550	1864	2672	1566	.216	.624	.908	.718
Odds	2:1	41:1	56:1	48:1	2:1	40:1	78:1	46:1

the other two sets. It was evident that maximum increases from phosphorus in these combinations had been passed in Treatments 442 and 444.

(4) K_2O 25 pounds per acre constant (Table 4). Phosphorus was most effective with the low nitrogen dosage (Set 1x1). In Set 2x1 the maximum increase occurred with Treatment 221. Phosphorus dosages in Set 4x1 failed to give any substantial gains.

(5) K_2O 50 pounds per acre constant (Table 5). The maximum increase from phosphorus occurred with Treatment 122 in Set 1x2. When the nitrogen dosage was doubled (Set 2x2), the maximum increase ap-

TABLE 23.—INCREASES IN YIELDS OF SWEET CORN DUE TO VARYING TREATMENTS OF SUPERPHOSPHATE AND POTASSIUM CHLORID WITH A QUADRUPLE DOSAGE OF SODIUM NITRATE CONSTANT

(Figures indicate mean increases per acre over adjacent check plots)

Potash series	Phosphorus series							
	40x	41x	42x	44x	40x	41x	42x	44x
	Number of ears				Tons marketable ears			
No clover in rotation								
4x0	−666	1616	2842	148	−.278	.578	.914	.027
Odds	4:1	39:1	35:1	1:1	4:1	58:1	66:1	1:1
4x1	243	34	−236	1650	.114	−.074	−.103	.566
Odds	9:1	<1:1	2:1	26:1	6:1	2:1	2:1	74:1
4x2	1124	364	1637	−6	.209	.051	.458	.071
Odds	5:1	2:1	32:1	<1:1	14:1	1:1	28:1	1:1
4x4	−902	875	2957	−909	−.331	.358	.804	−.251
Odds	9:1	3:1	>9999:1	8:1	25:1	6:1	10:1	5:1
First year after clover								
4x0	49	1236	1459	849	.028	.314	.595	.310
Odds	1:1	8:1	11:1	5:1	4:1	5:1	22:1	5:1
4x1	1249	824	1596	1200	.475	.342	.550	.544
Odds	155:1	4:1	10:1	21:1	28:1	6:1	7:1	26:1
4x2	315	590	1555	448	.054	.333	.429	.231
Odds	3:1	6:1	239:1	5:1	2:1	12:1	79:1	9:1
4x4	−485	1132	1676	586	−.131	.371	.557	.212
Odds	4:1	5:1	505:1	9:1	3:1	4:1	495:1	6:1
Second year after clover								
4x0	−822	−187	1914	1960	−.162	.036	.778	.672
Odds	5:1	2:1	26:1	3332:1	3:1	8:1	72:1	2499:1
4x1	768	1410	1717	1636	.295	.583	.658	.608
Odds	5:1	19:1	14:1	78:1	10:1	20:1	38:1	158:1
4x2	−1450	1076	2263	1677	−.405	.294	.881	.659
Odds	16:1	22:1	157:1	42:1	6:1	25:1	510:1	237:1
4x4	1000	2541	1556	835	.261	.984	.654	.427
Odds	5:1	41:1	27:1	55:1	3:1	65:1	60:1	39:1

peared with Treatment 242. Quadrupled nitrogen dosages (Set 4x2) materially reduced increases in yield, except that from Treatment 422.

(6) K_2O 100 pounds per acre constant (Table 6). Phosphorus gave successively larger increases in yield in combination with the single nitrogen dosage (Set 1x4) until the maximum for the three sets was reached at Treatment 144. With the doubled nitrogen dosage (Set 2x4) the single dosage of phosphorus gave increases in yield practically as large as those from either of the heavier dosages. In combination with 30 pounds of

nitrogen per acre, phosphorus in Set 4*x*4 gave successively larger increases except with Treatment 444.

Second Year After Clover.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). Increases in yield were very large. In combination with all three potash dosages, yields measured by weights of marketable ears increased in relation to the dosage of phosphorus except with Treatment 124. As measured by numbers of marketable ears, the treatments giving largest increases in the respective sets were Nos. 121, 112, and 144.

(2) Nitrogen 15 pounds per acre constant (Table 22). Increases were again very large, and in several cases they became successively larger in relation to the amount of phosphorus applied. Exceptions occurred in Treatments 242 and 244, in which the phosphorus dosages were evidently heavier than needed for maximum yields.

(3) Nitrogen 30 pounds per acre constant (Table 23). Increases in yield became successively larger in relation to the dosage of phosphorus in Sets 4*x*1 and 4*x*2, except in the heaviest dosages (Treatments 441 and 442). In Set 4*x*4 the single phosphorus dosage (Treatment 414) gave the largest increase.

(4) K_2O 25 pounds per acre constant (Table 4). Phosphorus gave successively larger increases in yield with the larger dosages, except in Treatment 441.

(5) K_2O 50 pounds per acre constant (Table 5). Phosphorus gave large increases in yield, but treatments involving quadruple phosphorus dosages, when combined with double and quadruple nitrogen dosages, were evidently heavier than was necessary to give maximum increases in weights of marketable ears. On the basis of number of marketable ears, the double dosage of phosphorus gave largest increases in combinations containing nitrogen in double and quadruple amounts, but the single dosage of phosphorus gave largest increases when combined with the single dosage of nitrogen.

(6) K_2O 100 pounds per acre constant (Table 6). In Set 1*x*4 the heaviest phosphorus dosage gave the largest increase, but the trend was broken at Treatment 124. In Set 2*x*4 the maximum increase occurred with Treatment 224, and in Set 4*x*4 with Treatment 414.

Phosphorus, in the foregoing "complete" fertilizer combinations, gave consistent increases in sweet-corn yields when used with certain dosages of nitrogen and potash, but gave erratic responses when other dosages of nitrogen and potash were used. Both with no clover in rotation and during the first and second years after clover, phosphorus gave substantial increases in yield when used with the smallest nitrogen dosage (7.5 pounds per acre). Effects of phosphorus in relation to potash in the complete fertilizers were somewhat obscured by relations between nitrogen and potash; but, in general, in combinations containing the smallest nitrogen dosage, heavy phosphorus dosages and light potash dosages, or light phosphorus dosages and heavy potash dosages resulted in increases in sweet-corn yields.

Analysis of Relative Phosphorus Efficiency in Different Combinations

Efficiency of Phosphorus When Used With Nitrogen.—Analysis of the relations between nitrogen and phosphorus by means of efficiency factors gives more specific information than does an analysis on the basis of yields alone. Both Table 24, showing the effects of nitrogen on the mean efficiency of phosphorus, and Table 25, listing the maximum percentages of increase in phosphorus efficiency, reveal

TABLE 24.—EFFECT OF NITROGEN ON PHOSPHORUS EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean phosphorus efficiency	Set	Mean phosphorus efficiency	Set	Mean phosphorus efficiency
	perct.		*perct.*		*perct.*
01*x*	21.48 ± 2.7	02*x*	18.10 ± 2.2	04*x*	35.35 ± 2.8
11*x*	26.17 ± 3.3	12*x*	37.17 ± 3.7	14*x*	42.07 ± 4.1
21*x*	21.03 ± 3.4	22*x*	29.38 ± 3.3	24*x*	28.99 ± 3.2
41*x*	16.46 ± 3.1	42*x*	30.40 ± 2.9	44*x*	13.10 ± 2.4

[a]See Table 40, Appendix, for detail data.

that the efficiency of phosphorus reached a maximum in combinations containing 7.5 pounds of nitrogen per acre. With respect to increased dosages of phosphorus, 128 pounds P_2O_5 per acre proved the most efficient dosage when nitrogen was omitted; when nitrogen was included 64 pounds P_2O_5 per acre proved more efficient than 128 pounds in two out of three combinations.

Comparison of the maximum percentage increases in yield listed in Table 26 likewise shows the dominance of 7.5 pounds nitrogen per acre, but not of 64 pounds P_2O_5. The combinations giving the maximum increases were:

Without nitrogen	Treatment 044
With 7.5 pounds nitrogen	Treatment 144
With 15 pounds nitrogen	Treatments 212, 220, or 221
With 30 pounds nitrogen	Treatment 420

The effects of phosphorus are somewhat obscured in Table 26 by the relationship existing between nitrogen and potash. The reader will note that as the nitrogen dosage increases there is a tendency for the potash requirement to decrease (see discussion of nitrogen-potash relations, pages 387 to 389). It appears also that by using the proper amount of nitrogen the maximum efficiency of phosphorus can be attained with a very much smaller dosage than otherwise.

TABLE 25.—EFFECT OF NITROGEN ON PHOSPHORUS EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN PHOSPHORUS EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Phosphorus efficiency	Treatment	Phosphorus efficiency	Treatment	Phosphorus efficiency
	perct.		*perct.*		*perct.*
014	24.04 ± 6.3[b]	021	27.73 ± 5.1	041	46.39 ± 5.5
114	43.24 ± 6.4	121	46.88 ± 6.8	144	60.28 ± 8.6
212	34.86 ± 7.9	221	39.09 ± 5.5	241	33.37 ± 5.1
414	32.36 ± 7.9	420	43.83 ± 5.1	440	20.58 ± 4.8

[a]See Table 40, Appendix, for detail data.
[b]Treatment 010 had an efficiency of 22.63 ± 4.8 percent.

This relationship between phosphorus and nitrogen is also evident from the data presented in Table 24, according to which the greatest efficiency in each series is shown to have coincided with certain well-defined combinations, as follows:

	Mode of the curve		*Next highest*		
Sets compared	*Set*	*Efficiency factor*	*Set*	*Efficiency factor*	*Difference*
01*x*-02*x*-04*x*	04*x* = 35.35 ± 2.8		01*x* = 21.48 ± 2.7		13.87 ± 3.9
11*x*-12*x*-14*x*	14*x* = 42.07 ± 4.1		12*x* = 37.17 ± 3.7		4.90 ± 5.5
21*x*-22*x*-24*x*	22*x* = 29.38 ± 3.3		24*x* = 28.99 ± 3.2		.39 ± 4.6
41*x*-42*x*-44*x*	42*x* = 30.40 ± 2.9		41*x* = 16.46 ± 3.1		13.94 ± 4.2

Set 04*x* is thus shown to have been significantly higher in efficiency than the next ranking set. The difference in efficiency between Sets 14*x* and 12*x*, and also between Sets 22*x* and 24*x*, was too slight to be significant. Set 42*x* was, however, significantly more efficient than Set 41*x*. Thus Sets 04*x*, 12*x*, 22*x*, and 42*x* were either the highest, or virtually equal to the highest, in efficiency, indicating that in no instance is it necessary to use as much phosphorus when nitrogen forms a part of the combination as when nitrogen is omitted.

Data in Table 25 bear out this conclusion when subjected to the same analysis (table should be read horizontally). Treatments 041,

TABLE 26.—EFFECT OF NITROGEN ON PHOSPHORUS AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, I	014	27.62 ± 5.4	024	21.36 ± 3.4	044	43.50 ± 6.5
12, J	114	38.54 ± 5.1	122	44.47 ± 8.1	144	55.58 ± 7.7
12, K	212	31.95 ± 6.3	221	31.92 ± 5.2[a]	240	29.16 ± 4.1
12, L	414	30.12 ± 7.0	420	38.98 ± 4.4	441	24.94 ± 2.7

[a]Treatment 220 gave an increase of 31.50 ± 4.8 percent.

114, 212, and 414 are either the modes in each series, or not significantly less than the modes.

Unfortunately no chemical analyses were made of the soils and plants in these investigations and, therefore, an adequate explanation of these phenomena is out of the question. There is a possibility, however, that the added sodium nitrate increased the availability of the phosphates. Wagner,[54*] Greaves,[24*] Patten,[41*] and Spurway[45*] all have shown that sodium nitrate increases the availability of certain insoluble phosphates. Breazeale,[11*] in culture solution studies with wheat seedlings, reached the conclusion that the absorption of phosphoric acid appears to be increased slightly by sodium nitrate. Fudge[20, 21*] found that nitrogenous salts which leave a sodium residue increase phosphate availability considerably. Greaves and Carter[25*] and MacTaggart,[36*] on the other hand, reached conclusions which indicate that sodium nitrate has no effect on the availability of phosphates, and Marais[37*] states that Prianishnikov and other Russian workers conclude that sodium nitrate may not only be ineffective, but actually depressing to the availability of phosphorus.

The contradictory nature of the above citations is perhaps due to the types of soils or culture solutions used in the various experiments. However, the important point to consider is that, whatever the reason, nitrate of soda reacted in the soils used in these experiments in a manner that would seem to indicate that it does increase the availability of phosphorus.

Efficiency of Phosphorus When Used With Potassium.—The efficiency of phosphorus was affected also by the potash used in combination with it, as shown in Tables 27, 28, and 29.

Set $x14$ had the highest phosphorus efficiency among the sets in which the single dosage of phosphorus was constant (Sets $x10$, $x11$, $x12$, $x14$) (Table 27). Where the double dosage was constant (Sets $x20$, $x21$, $x22$, $x24$), Set $x22$ had the highest phosphorus efficiency,

TABLE 27.—EFFECT OF POTASH ON PHOSPHORUS EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean phosphorus efficiency	Set	Mean phosphorus efficiency	Set	Mean phosphorus efficiency
	perct.		*perct.*		*perct.*
$x10$	14.32 ± 2.7	$x20$	27.92 ± 2.5	$x40$	24.18 ± 2.8
$x11$	16.17 ± 3.0	$x21$	29.67 ± 3.2	$x41$	33.12 ± 3.1
$x12$	24.80 ± 3.2	$x22$	31.84 ± 3.4	$x42$	29.64 ± 3.4
$x14$	29.86 ± 3.6	$x24$	25.64 ± 3.1	$x44$	32.57 ± 3.5

[a]See Table 40, Appendix, for detail data.

TABLE 28.—EFFECT OF POTASH ON PHOSPHORUS EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN PHOSPHORUS EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Phosphorus efficiency	Treatment	Phosphorus efficiency	Treatment	Phosphorus efficiency
	perct.		*perct.*		*perct.*
010	22.63 ± 4.8	420	43.83 ± 5.1	240	32.07 ± 4.6
011	22.89 ± 4.8	121	46.88 ± 6.8	041	46.39 ± 5.5
212	34.86 ± 7.9	122	42.58 ± 9.4	142	38.22 ± 7.5
114	43.24 ± 6.4	424	37.77 ± 4.5	144	60.28 ± 8.6

[a]See Table 40, Appendix, for detail data.

but only by a small margin. Where the quadruple dosage was constant (Sets $x40$, $x41$, $x42$, $x44$), Set $x41$ had the highest efficiency. Thus the character of the three modal sets, $x14$, $x22$, $x41$—which were very nearly alike in efficiency, having factors of 29.86 ± 3.6, 31.84 ± 3.4, and 33.12 ± 3.1 respectively—indicates that an inverse relationship existed between phosphorus and potash.

A similar relationship is shown when the maximum increases in phosphorus efficiency in relation to potash are compared (Table 28). The modes in each set were as follows:

	Efficiency factor
Treatment 114	43.24 ± 6.4
Treatment 121	46.88 ± 6.8
Treatment 144	60.28 ± 8.6

These modes do not quite agree with the modes in Table 27. The fact that Treatment 121 is higher than Treatment 122 does not interfere with the idea of the inverse relationship between phosphorus and potash, but Treatment 144 is clearly out of line with that theory. The only possible explanation of this apparent inconsistency seems to be that in Table 27 the group with the quadruple dosage of phosphorus constant (Sets $x40$, $x41$, $x42$, $x44$) tends to be bimodal, with sets $x41$

TABLE 29.—EFFECT OF POTASH ON PHOSPHORUS AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, E	010	22.63 ± 4.8	420	38.98 ± 4.4	140	30.12 ± 6.1
12, B	411	16.06 ± 5.1	121	34.47 ± 4.7	041	37.41 ± 4.8
12, C	112	34.73 ± 5.3	122	44.47 ± 8.1	142	40.11 ± 5.8
12, D	114	38.54 ± 5.1	424	35.53 ± 2.5	144	55.58 ± 7.7

and $x44$ as the two modes. This might be expected inasmuch as Set $x22$, the mode when a double dosage of phosphorus was constant (Sets $x20$, $x21$, $x22$, and $x24$), has the same ratio of P to K as has Set $x44$. In Table 28, also, the sets having 128 pounds P_2O_5 per acre constant are bimodal and Treatments 041 and 144 are the modes. If this assumption is correct, Table 28 confirms the inverse relationship between phosphorus and potash which is shown in Table 27.

The data given in Table 29 on the relations between phosphorus and potash based on the maximum increases in yields are, for the most part, in agreement with the foregoing interpretation. The modes in each set were as follows:

	Percentage increase
Treatment 114	38.54 ± 5.1
Treatment 122	44.47 ± 8.1
Treatment 144	55.58 ± 7.7

Treatments 114 and 122 agree perfectly with what one would expect from the data in Table 27, but the uniformly upward trend (showing no tendency toward bimodality) in the last column of Table 29, with Treatment 144 as the mode, does not. This may not be of great importance, however, as the differences between the yields of Treatments 041 and 142 were very slight.

Thus it is apparent, especially from the data presented in Table 27, that in this experiment there existed an inverse relationship between phosphorus and potash in which phosphorus maintained a fairly stable equilibrium when the dosage increased at the same time the dosage of potash decreased. Altho there is no direct evidence of this relationship, because of lack of chemical analyses, this action apparently indimates that increases in the amount of potash applied to such soils as those under test tend to make phosphorus more available, so that small quantities of phosphorus applied in combination with large quantities of potash are just as effective as large quantities of phosphorus combined with small quantities of potash. A tendency also existed for large quantities of both elements in combination to be slightly more efficient, as shown by Set $x44$ and Treatment 144. A great deal of experimental work has been done on the question of the relations between phosphorus and potash, and some of the present results suggest a reason for the inverse relationship which has been noted, but unfortunately they do not provide the connecting link between crop yields and chemical phenomena..

Thomson[50*] showed that the solubility of phosphoric acid from superphosphate is not affected by 1- or 2-percent solutions of potassium nitrate. That the effect of potassium chlorid and other salts on

the solubility of phosphorus seems to be slight was the conclusion of Greaves,[24*] but this effect varied somewhat, according to the form of phosphorus, and increased when soil was added. Patten[41*] passed weak solutions of the salts KCl, K_2SO_4, KNO_3, $NaNO_3$, and Na_2CO_3 thru quartz flour, sandy soil and fine clay to all of which phosphorus had been added, and obtained an increased concentration of phosphates compared with distilled water checks. He concluded that the solubility of the phosphorus is not increased directly, but that the increase is actually due to a disturbance and rearrangement of the equilibrium between the soluble material retained by the soil and soil solution. Likewise Greaves and Carter[25*] studied the effects of KNO_3 and KCl on the solubility of soil phosphorus, and concluded that these salts increase the water-soluble phosphorus in the soil because of their action on soil microorganisms but not because of any direct solvent action. They showed that aqueous solutions of KNO_3 and KCl dissolve no more phosphorus from raw rock phosphate than does distilled water. In a leaching experiment with acid and alkaline sandy loams, Spurway[45*] found that $NaNO_3$, NaCl, KCl, $CaCO_3$, and $CaSO_4$, in the order given, increased the percentage of P_2O_5 in soil extracts. Later Spurway[46*] found that added KCl increased the solubility of phosphorus in $CaH_4(PO_4)_2$, and concluded that the salts of sodium and potash seem to hold applied phosphorus in a more soluble condition. According to Hock[28*] P_2O_5 and K_2O salts gave higher recoveries for both when used in combinations than when used singly. The effects are by no means the same, however, for the absorption of P_2O_5 is influenced much more than that of K_2O. In studies with the Neubauer test Thornton[51*] found the absorption of phosphorus to be slightly increased by applications of potash. Later, however, Thornton[52*] showed that the recovery of phosphorus in Neubauer tests is considerably increased when potash in the form of potassium chlorid is added to different forms of phosphorus.

Altho the results of some of the early percolation and leaching experiments fail to show that potash increases the availability of phosphorus, it is evident from later work, as shown by the above review, that such must be the case. In view of the large increases in phosphorus efficiency which have been obtained by the use of potash in the experiments herein reported, the authors conclude that this indirect action of potash may be just as important as its direct action. It may be assumed that potash exerts a very marked influence in increasing the utilization of phosphorus by the plant.

Selection of Possible Optimum Ratios on Basis of Nitrogen and Phosphorus Efficiencies

The foregoing analysis of the relations between phosphorus and potash will serve to elucidate the somewhat conflicting results which have been obtained with the treatments containing the three elements—nitrogen, phosphorus, potassium. The fertilizer combinations most closely approaching the optimum may also be selected with considerably greater certainty.

From the analysis of the results of side-dressing nitrogen, the requirements of an optimum treatment when nitrogen was used in that way were found to be: (1) not more than 7.5 pounds nitrogen per acre when nitrogen was used with phosphorus and potash; (2) 64 pounds P_2O_5 as a supplement to 7.5 pounds nitrogen when phosphorus was used in the combination; and (3) not more than 50 pounds K_2O as a supplement to 7.5 pounds nitrogen per acre when potash was part of the treatment. Treatments 121 and 122 fulfill these requirements from the standpoint of nitrogen efficiency.

In regard to the phosphorus dosage it was shown in the foregoing discussion that phosphorus attains it greatest efficiency in combinations containing 7.5 pounds nitrogen per acre, and further that the dosage of 64 pounds of P_2O_5 per acre is the optimum quantity to use as a basal treatment. Where nitrogen is excluded entirely, 128 pounds P_2O_5 is more efficient than 64 pounds. Thus far, Treatments 121 and 122 fulfill all requirements perfectly for both nitrogen and phosphorus.

However, the question of the relations existing between phosphorus and potash must also be considered. As stated previously, phosphorus maintains an equivalent efficiency in three combinations, namely $x14$, $x22$, and $x41$; and $x21$ is only slightly below these. The combination $x14$, or 114 as shown by Table 28, might be discarded perhaps, as 7.5 pounds nitrogen plus 32 pounds P_2O_5 per acre has been shown to be much less efficient than 7.5 pounds nitrogen plus 64 pounds P_2O_5 per acre. The $x41$ combination may be retained, but only as Treatment 041, since the addition of nitrogen to 128 pounds P_2O_5 per acre results (1) in a reduction of nitrogen efficiency compared with the addition to 64 pounds P_2O_5 (Table 14), and (2) in no more than a slight increase in phosphorus efficiency (Table 24). Accordingly Treatment 041 may be retained as a possible optimum treatment. Likewise Treatment 121 may be retained, as the phosphorus efficiency of the combination $x21$ is almost the same as that of $x22$ (Table 27) and is slightly higher than Treatment 122 (Table 28).

Thus Treatments 121 and 122 fulfill, so far, the requirements of an optimum fertilizer ratio. Treatment 041, altho an incomplete fertilizer, may be added as the most promising combination of phosphorus and potassium.

EFFECTS OF POTASH

The effects of potash in relation to nitrogen and phosphorus have already been discussed in some detail in the sections dealing primarily with nitrogen and phosphorus. Accordingly this section contains some duplication of former statements repeated for clarity.

Tables 3 to 9 and 20 to 23, to which many references will be made, should be read vertically for potash comparisons.

Potash Alone

The use of potash alone as a fertilizer cannot be recommended, for there is some evidence that even small dosages act unfavorably on yields (Table 3). With no clover in the rotation, potash had virtually no effect on yields. During the first year after clover a dosage of 25 pounds K_2O per acre proved ineffective, and larger applications gave small but significant increases. During the second year after clover the results were variable, with small odds, and the tendency was for potash to depress yields.

The mean percentages of increase for the plots receiving potash alone, including all such plots in all positions in the rotation, show that 25 pounds K_2O per acre gave a significant decrease in yield and 50 and 100 pounds were not effective (Section A, Tables 11 and 12).

Potash Increasing, Nitrogen Constant

The relations between nitrogen-potash combinations have already been discussed at considerable length from the standpoint of nitrogen (pages 387 to 389), where it was pointed out that high variation in yields from nitrogen-potash fertilizers, with potash constant and nitrogen increasing, and the obvious absence of a specific trend indicate that phosphorus was the limiting factor in the soils of these experiments.

With no clover in the rotation the results obtained from increasing potash in relation to nitrogen were likewise highly variable and the odds of slight significance in nearly all cases (Table 3). During the first year after clover the results apparently followed no specific trend, and during the second year after clover they were extremely variable.

A comparison of the mean increases from the plots receiving nitrogen-potash combinations, including all such plots in all positions

in the rotation, also shows the absence of definite tendencies (Section A, Tables 11 and 12). A single treatment, No. 401, shows a definite and significant increase, which can hardly be accidental because the yields from four plots in as many fields over a period of six years are involved.

Potash Increasing, Phosphorus Constant

Phosphorus-potash fertilizer combinations with potash constant and phosphorus increasing were discussed above (pages 391-392) from the viewpoint of phosphorus, and substantial increases in yield and a certain inverse relationship between phosphorus and potash were pointed out.

Likewise, in the phosphorus-potash combinations with potash increasing and phosphorus constant, definite increases were obtained, and the effectiveness of potash was apparently determined by the quantity of phosphorus used (Table 20). Where no clover was included in the rotation, the maximum increases in yield in each set were gained with Treatments 012, 021, and 041 respectively. This resembles the order 014, 022, and 041 in which one would expect to find maximum increases, according to the inverse relationship apparently existing between phosphorus and potash. During the first year after clover potash gave no definite response in combination with low phosphorus applications. The modal treatments in each combination were Treatments 010, 022, and 042. During the second year after clover the modes were Treatments 014, 024 and 044. It is quite evident that in the second year after clover there was a tendency for yields to increase directly in relation to the quantity of potash applied.

The mean increases from the plots receiving the phosphorus-potash combinations, including all such plots in all positions in the rotation, show that the modal treatments were Treatments 014, 022, and 044 when yields were measured in terms of numbers of marketable ears (Section I of Table 11), and Treatments 014, 024, and 044 when yields were measured in terms of weights of marketable ears (Section I, Table 12). There is thus, according to these data, a fairly consistent tendency for the yields to increase directly in relation to increases in the applications of potash when used with phosphorus and without nitrogen.

Potash Increasing, Nitrogen and Phosphorus Constant

The fertilizer combinations discussed under this heading are complete analyses having different constants of nitrogen and phosphorus with potash varying. Sixteen treatment combinations are involved at each position in the rotation.

No Clover in Rotation.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). In combinations containing single dosages of nitrogen and phosphorus (Set 11*x*), Treatment 114, in accordance with expectation, gave the largest increase in yield. In Set 12*x* Treatment 120 gave the largest increase in number of ears and ranked only slightly below Treatment 122 with respect to weight of increase. Treatment 144 gave the largest increase in Set 14*x*.

(2) Nitrogen 15 pounds per acre constant (Table 22). Treatment 212 gave the maximum increase in Set 21*x*. Potash gave decreasing responses in Set 22*x*. In Set 24*x* only Treatment 244, containing the heaviest potash dosage, gave an increase over Treatment 240, containing no potash.

(3) Nitrogen 30 pounds per acre constant (Table 23). In Set 41*x* the treatment containing no potash (No. 410) gave the best results. This was also true in Set 42*x*, except that Treatment 424 gave a very small increase in number of ears over Treatment 420. In Set 44*x* Treatment 441 gave much the largest increase in yield.

(4) P_2O_5 32 pounds per acre constant (Table 7). Maximum increases in the three sets of treatments occurred with Treatments 114, 212, 410.

(5) P_2O_5 64 pounds per acre constant (Table 8). Excepting one very insignificant increase (weight of ears, Treatment 122), potash did not have any appreciable effect.

(6) P_2O_5 128 pounds per acre constant (Table 9). Maximum increases occurred with Treatments 144, 244, and 441.

First Year After Clover.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). Maximum increases in the three sets occurred with Treatments 112, 122, 144. Set 14*x* showed evidence of bimodality, with Treatments 141 and 144 as the modes. Bimodality would be expected from the results already discussed.

(2) Nitrogen 15 pounds per acre constant (Table 22). The modal treatments were Nos. 212, 221, 242. Only in ear weight in Set 24*x* was there any evidence of bimodality (Treatments 240 and 242).

(3) Nitrogen 30 pounds per acre constant (Table 23). The modal treatments, measured by increases in ear weights, were Nos. 414, 420, 441. Measured by increases in number of ears, Treatments 410, 424, 441 ranked as the modes. The increases due to potash were in general rather small.

(4) P_2O_5 32 pounds per acre constant (Table 7). The modes of the three sets were Treatments 112, 212, and 414 with respect to ear weight, and Treatments 112, 212, and 410 in number of ears.

(5) P_2O_5 64 pounds per acre constant (Table 8). The modes with respect to ear weight were Treatments 122, 221, and 420. For number of ears they were Treatments 122, 221, and 424.

(6) P_2O_5 128 pounds per acre constant (Table 9). The modes were Treatments 144, 242, and 441 for both number and weight of marketable ears.

Second Year After Clover.—(1) Nitrogen 7.5 pounds per acre constant (Table 21). The modes were Treatments 112, 121, and 144. With respect to number of ears there was evidence of bimodality in Set 14*x*, Treatments 141 and 144 being the modes; but in weight of ears, Treatment 142 was very slightly higher than Treatment 141.

(2) Nitrogen 15 pounds per acre constant (Table 22). In these three sets the modal treatments were Nos. 212, 222, and 241. There was no evidence of bimodality with high phosphorus dosage constant (Set 24*x*).

(3) Nitrogen 30 pounds per acre constant (Table 23). The three modes were Treatments 414, 422, 440 both for number and weight of marketable ears. Potash had a slight negative effect upon yields in Set 44*x*.

(4) P_2O_5 32 pounds per acre constant (Table 7). The modal treatments were Nos. 112, 212, and 414. All of these showed very large increases due to potash.

(5) P_2O_5 64 pounds per acre constant (Table 8). The modes were Treatments 121, 222, and 422 for both number and weight of marketable ears.

(6) P_2O_5 128 pounds per acre constant (Table 9). The modes of the three sets were Treatments 144, 241, and 440. Treatment 141 was almost as high as Treatment 144. In fact, potash showed only very small increases in yield as the dosages reach 50 and 100 pounds K_2O per acre.

In the foregoing "complete" fertilizers the action of potash was apparently affected by both nitrogen and phosphorus, and did not give the same results as in phosphorus-potash combinations. In general, inverse relationships were apparent between potash and nitrogen and between potash and phosphorus.

Analysis of Relative Potash Efficiency in Different Combinations

Efficiency of Potash When Used With Nitrogen.—The effect of nitrogen on the efficiency of potash is shown in Tables 30, 31, and 32. All of the efficiency factors in Table 30 are low and, with the exception of those for Sets 1*x*2, 0*x*4, and 1*x*4, they are very low indeed. The only significant factor is that for the set having no nitrogen dosage (0*x*4). In fact, the only definite trend developing from the data presented in Table 30 does not concern potash-nitrogen relations at all, but is the increase in efficiency in Sets 0*x*1, 0*x*2, and 0*x*4, indicating that in phosphorus-potash mixtures the efficiency of potash increases in

TABLE 30.—EFFECT OF NITROGEN ON POTASH EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean potash efficiency	Set	Mean potash efficiency	Set	Mean potash efficiency
	perct.		*perct.*		*perct.*
0*x*1	2.25 ± 2.6	0*x*2	5.83 ± 2.7	0*x*4	10.99 ± 2.9
1*x*1	−3.32 ± 3.5	1*x*2	11.00 ± 3.8	1*x*4	10.84 ± 3.6
2*x*1	.67 ± 3.1	2*x*2	5.48 ± 3.5	2*x*4	2.87 ± 3.4
4*x*1	4.04 ± 3.2	4*x*2	−2.59 ± 2.7	4*x*4	1.16 ± 3.0

[a]See Table 40, Appendix, for detail data.

TABLE 31.—EFFECT OF NITROGEN ON POTASH EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN POTASH EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Potash efficiency	Treatment	Potash efficiency	Treatment	Potash efficiency
	perct.		*perct.*		*perct.*
041	17.96 ± 6.2	042	17.83 ± 6.0	044	24.05 ± 7.6
121	5.54 ± 6.1	112	22.11 ± 5.9	114	25.92 ± 5.8
211	9.49 ± 7.4	212	26.99 ± 8.4	214	20.14 ± 7.6
401	22.23 ± 4.2	402	1.84 ± 5.0	414	15.31 ± 8.5

[a]See Table 40, Appendix, for detail data.

relation to the dosage. When nitrogen was increased with potash held constant (Table 30), the maximum efficiencies occurred in Sets 4*x*1, 1*x*2, and 0*x*4, respectively, in the three groups being considered. This apparently indicates an inverse relationship between nitrogen and potash, which is confirmed by similar modes in Table 31. But the maximum increases in yield shown in Table 35 do not confirm this interpretation, for here yield and efficiency analyses do not coincide. This discrepancy was not entirely unexpected, because in dealing with yields alone, the influence of single elements cannot be segregated, and the weaker relations between nitrogen and potash may be entirely masked by the stronger relations between nitrogen and phosphorus.

This tendency toward an inverse relationship between nitrogen and potash is brought out in the following comparison of maximum nitrogen and potash efficiencies:

Maximum nitrogen efficiency (percentage)		*Maximum potash efficiency (percentage)*	
(*Set averages from Table 17*)		(*Set averages from Table 30*)	
Set 1*x*2	11.44 ± 3.7	Set 0*x*4	10.99 ± 2.9
Set 2*x*0	2.65 ± 2.7	Set 1*x*2	11.00 ± 3.8
Set 4*x*2	5.28 ± 2.7	Set 4*x*1	4.04 ± 3.2
(*Modes from Table 18*)		(*Modes from Table 31*)	
Treatment 122	25.95 ± 9.3	Treatment 114	25.92 ± 5.8
Treatment 220	21.48 ± 5.5	Treatment 212	26.99 ± 8.4
Treatment 420	28.96 ± 5.2	Treatment 401	22.23 ± 4.2

The average nitrogen efficiencies in Sets 2*x*0 and 4*x*2 are too small to warrant any comments. In Treatments 122, 220, and 420, however, the nitrogen efficiency remains fairly constant, and it should be noted that as nitrogen dosages increase potash dosages are reduced or eliminated, with the efficiencies remaining nearly constant. Similarly, in Treatments 114, 212, and 401 the potash efficiency remains fairly constant only when the nitrogen and potash dosages are in inverse relation.

These data have been checked by calculating the factors for green

TABLE 32.—EFFECT OF NITROGEN ON POTASH AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, I	041.....	37.41 ± 4.8	042.....	37.28 ± 4.5	044.....	43.50 ± 6.5
12, J	121.....	34.47 ± 4.7	122.....	44.47 ± 8.1	144.....	55.58 ± 7.7
12, K	221.....	31.92 ± 5.2	212.....	31.95 ± 6.3	244.....	27.27 ± 3.1
12, L	441.....	24.94 ± 2.7	422.....	32.04 ± 3.2	424.....	35.53 ± 2.5

fodder. On the green fodder basis the agreement between nitrogen and potash efficiency is much better defined than it is when based on marketable ears.

The inverse relationship between nitrogen and potash is of great importance in determining optimum fertilizer ratios. Owing to the lack of chemical analyses in these experiments, the exact meaning of such an inverse relationship can only be inferred. Chemical studies bearing upon this problem have, however, been made by a number of other investigators.

Huston[32*] stated that the sodium in 100 pounds sodium nitrate is capable of releasing 55 pounds of potash from zeolites, and André[1*] concluded that sodium nitrate in addition to furnishing available nitrogen is valuable because it sets potassium free. Spurway,[45*] however, found that sodium nitrate is one of a number of salts which have a tendency to depress the solubility of potash.

Hoagland and Davis[27*] explained the relations between sodium and potassium by suggesting that cations may be interrelated in the process of plant absorption. A relatively high concentration of Na ions may depress the absorption of K or Ca ions. Anions they found may show similar relations, as in Nitella the rate of penetration of NO_3 ions into the cell sap is significantly depressed by the presence of Cl ions in the solution.

Thus present opinion, as represented by these citations, apparently supports the idea that sodium nitrate in large amounts does not increase but actually depresses the availability of potash, probably because of the Na ions present from added $NaNO_3$, but that, on the other hand, when KCl is added, the absorption of NO_3 is retarded by the Cl ions.

Greaves, Carter, and Goldthorpe[26*] have investigated the problem of nitrogen-potassium relations from the viewpoint of the soil biologist and have shown that sodium nitrate fails to stimulate nitrification but

that potash used in the form of KNO_3 and KCl acts as a stimulant. Stimulation occurs only in certain concentrations which, if exceeded, increase very rapidly into toxicity.

In work with culture solutions Breazeale[10*] found that wheat seedlings demand more potash when nitrogen is omitted. On the other hand, he found[11*] in later work that nitrogen absorption from sodium nitrate by wheat seedlings is not affected by potassium sulfate, sodium phosphate, or calcium sulfate. He found, also, that the absorption of potash from the nutrient solution increases when salts containing plant foods are added, and that this is more marked with salts containing nitrates than with others. Breazeale[11*] apparently reached conclusions somewhat different from those of Hoagland and Davis,[27*] who state that Cl anions which are added in potassium chlorid depress in turn the absorption of NO_3. This difference in conclusions may be due to the fact that Breazeale used potassium sulfate instead of the chlorid.

Another aspect of the relations between potash and nitrogen is presented by Janssen and Bartholomew,[33*] who, in work with tomatoes, found that the percentage of water-soluble and total nitrogen was greater in plants receiving low potash than in those treated with high potash. A high percentage of potash seems to be correlated with a low percentage of nitrogen in fertilizer ratios when the former element is present in the soil in amounts insufficient for normal growth. In later work Janssen and Bartholomew[34*] showed that there is more succulence in plants receiving high than in those receiving low potash, but that the dry weight decreases in relation to increases of potash.

Clements[14*] in working with Scotch Beauty field peas concluded that total carbohydrates are most abundant where plants are grown in solutions containing the highest percentage of nitrates. In contrast, the highest percentages of organic nitrogen are found where the highest application of potash is used. The best plants, according to Clements are found between the two extremes.

Thus it is evident from these citations, as well as from the data collected in the experiments reported herein, that the relations existing between potash and nitrogen are complex in nature. In the selection of optimum ratios in complete fertilizers it is apparently more difficult to choose among various potash-nitrogen combinations than among either potash-phosphorus or phosphorus-nitrogen combinations.

Efficiency of Potash When Used With Phosphorus.—Phosphorus also exerts a considerable influence on potash, as shown by the data in Tables 33, 34, and 35.

Potash and phosphorus, as indicated in the preceding discussion

TABLE 33.—EFFECT OF PHOSPHORUS ON POTASH EFFICIENCY AS INDICATED BY SET AVERAGES BASED ON WEIGHTS OF MARKETABLE EARS[a]

Set	Mean potash efficiency	Set	Mean potash efficiency	Set	Mean potash efficiency
	perct.		*perct.*		*perct.*
$x01$	−2.23 ± 2.5	$x02$	− .04 ± 3.1	$x04$	1.05 ± 2.6
$x11$	− .38 ± 3.2	$x12$	10.45 ± 3.4	$x14$	16.59 ± 3.7
$x21$	− .48 ± 3.4	$x22$	3.88 ± 3.4	$x24$	−1.23 ± 3.0
$x41$	6.71 ± 3.3	$x42$	5.43 ± 3.6	$x44$	9.44 ± 3.6

[a]See Table 40, Appendix, for detail data.

of phosphorus efficiency (pages 397 to 402), are in inverse relationship with each other. This inverse relationship is, to a limited extent, evident from the data presented in Table 33, in which the maximum efficiencies for each potash constant are those for Sets $x41$, $x12$, and $x14$. Of these, only that for Set $x14$ is statistically significant. There is a tendency, however, for high potash and low phosphorus or, inversely, high phosphorus and low potash, to be associated in the modal treatments.

According to the data presented in Table 34, the maximum increases in potash efficiency for the respective potash constants occurred with Treatments 041, 212, and 114 if Treatment 401 is excluded because it contains no phosphorus. These phosphorus-potash combinations are the same as those that exhibited maximum potash efficiencies in Table 33. The maximum percentage increases in yields for the respective potash constants (Table 35) occurred with Treatments 041, 122, and 144; and assuming Treatment 144 to be one mode in a bimodal curve, as in the previous discussion, Treatment 114 would be the other mode. Again the data point to an inverse relationship between phosphorus and potash.

Altho, as previously stated (page 401), these phosphorus-potash re-

TABLE 34.—EFFECT OF PHOSPHORUS ON POTASH EFFICIENCY AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN POTASH EFFICIENCY IN THEIR RESPECTIVE SETS[a]

Treatment	Potash efficiency	Treatment	Potash efficiency	Treatment	Potash efficiency
	perct.		*perct.*		*perct.*
401	22.23 ± 4.2	402	1.84 ± 5.0	204	8.23 ± 6.3
211	9.49 ± 7.4	212	26.99 ± 8.4	114	25.92 ± 5.8
021	8.73 ± 5.1	122	15.54 ± 9.0	024	11.34 ± 4.3
041	17.96 ± 6.2	042	17.83 ± 6.0	144	25.46 ± 9.8

[a]See Table 40, Appendix, for detail data.

TABLE 35.—EFFECT OF PHOSPHORUS ON POTASH AS INDICATED BY TREATMENTS THAT GAVE MAXIMUM PERCENTAGE INCREASES IN WEIGHTS OF MARKETABLE EARS IN THEIR RESPECTIVE SETS

Table from which data are taken	Treatment	Increase in yield	Treatment	Increase in yield	Treatment	Increase in yield
		perct.		*perct.*		*perct.*
12, A	401.....	17.38 ± 3.3	102.....	1.89 ± 4.7	204.....	5.32 ± 5.9
12, F	411.....	16.06 ± 5.1	112.....	34.73 ± 5.3	114.....	38.54 ± 5.1
12, G	121.....	34.47 ± 4.7	122.....	44.47 ± 8.1	424.....	35.53 ± 2.5
12, H	041.....	37.41 ± 4.8	142.....	40.11 ± 5.8	144.....	55.58 ± 7.7

actions cannot be explained absolutely, because no chemical analyses are available, it is quite probable that the inverse relationship that appears to exist is a result of changes in the availability of soil potash in the presence of phosphorus. Current opinions of soil chemists on the interactions of phosphorus and potash, however, are far from agreement. Among those who hold in general that phosphorus does not increase the availability of potassium are Tressler and Spurway. Tressler,[53*] who worked with Dunkirk silt loam, found that additions of di- and tri-calcium phosphate had no effect on the availability of soil potash, that monocalcium phosphate, on the other hand, had a negative effect, but that calcium sulfate liberated potash in appreciable quantities. Since superphosphate contains all three forms of calcium phosphate as well as calcium sulfate, it might be assumed that the latter salt was entirely responsible for the action observed. Spurway[45*] went further still against the belief that phosphorus liberates soil potash when he observed that not only monocalcium phosphate, but tricalcium phosphate and even superphosphate itself depressed the solubility of potassium in the soil. Thornton,[51*] however, obtained merely neutral results. By means of the Neubauer test he found that potash absorption was not affected by any concentration of phosphorus used in his experiments.

Opposed to these conclusions are the findings of a number of other investigators. Huston[32*] stated that the calcium sulfate in 100 pounds of ordinary superphosphate is capable of releasing 18 pounds of potash. Curry and Smith[17*] observed that superphosphate in contact with five different soil types liberated considerable quantities of potassium, and they believed that similar reactions occur in the field. Emerson and Barton[19*] found that the solubility of soil potassium, as indicated by its recovery from plants, was increased by superphosphate, manure, and combinations of both. Hock[28*] found that combinations of phosphorus and potash salts increased their mutual recovery as compared with

recovery of each when applied singly, but that, in the combination, the absorption of P_2O_5 appeared to be affected much more than that of K_2O. Neubauer, Bonewitz, and Schottmüller,[40*] using the Neubauer test on different soil types, found an apparent increase in potash absorption by plants following the use of stall manure, basic slag, and superphosphate. This increased absorption by the plants was actually due to the increased availability of soil potash. Superphosphate apparently decreased the absorption of potash by soil. Dreyspring and Heinrich,[18*] also using the Neubauer method, found that the solubility of soil potash was increased by applications of superphosphate and Thomas slag. They believed that this activation of potassium was due to free H_3PO_4 and $CaH_4(PO_4)_2$. They acknowledged, however, that calcium sulfate may also have had some effect. Since phosphoric acid in applied fertilizers seems capable of increasing the root-solubility of soil potassium, they assumed that, conversely, the potash in fertilizers can also activate the phosphoric acid in the soil. In conclusion they stated that phosphoric acid will increase the absorption of potash from fertilizers as well as from the soil, and that added potash may increase the absorption of both added and soil phosphoric acid.

It will be observed that Dreyspring and Heinrich agree with Neubauer *et al,* but reach conclusions which are quite different from those of Thornton. In general, opinion on this subject is very much divided. It is quite possible that the conflict in results obtained might be traceable to the different soils which were used by the various investigators. Apparently, as indicated by the greater efficiency of potash in certain potash-phosphorus combinations used in these experiments, the responses of the Illinois soils tested here are such that potash availability is increased to some extent by the addition of phosphorus.

Selection of Possible Optimum Ratios on Basis of Potash Efficiency

Upon a basis of nitrogen and phosphorus efficiencies Treatments 041, 121, and 122 survived (page 403), as apparently fulfilling the requirements of optimum treatments for sweet corn on the soils used in these experiments. Upon the basis of potash efficiency, however, these treatments were not particularly outstanding. Of course it must be remembered that the mean efficiency of potash in relation to nitrogen (Table 30) was relatively low in all types of combinations. Treatments $1x2$, $0x4$, and $1x4$ were the highest in potash efficiency, but only Treatment $0x4$ has an efficiency factor more than 3.2 times its probable error. Treatments of the $0x1$ and $1x1$ types fluctuate around

zero in potash efficiency. Treatment 041 has a potash efficiency in relation to nitrogen of 17.96 ± 6.2 (Table 31), Treatment 121 an efficiency of 5.54 ± 6.1, but Treatment 122 does not appear. A point of considerable interest is the high potash efficiency of Treatment 114, which is 25.92 ± 5.8.

When the effect of phosphorus on mean potash efficiency is examined (Table 33) Set $x14$, with an average factor of 16.59 ± 3.7, is the only one that proves statistically significant. Treatments 041, 121, and 122 can scarcely be eliminated because of their low potash efficiency, however, since this condition seems to be the rule in all types of treatments except $x14$. Since Treatment 114 has a high individual potash efficiency, 25.92 ± 5.8 (Table 31), it is added to the list of tentative optimum treatments, the discussion of which will be resumed later (page 419).

INFLUENCE OF FERTILIZERS ON MATURITY

From the standpoint of the crop, commercial fertilizers are used for two purposes—to increase the total yield and to advance maturity.

A great deal of experimental work has been conducted on fertilizers and their effects on maturity. The literature reporting this work need not be reviewed here, because the results of the experiments under discussion do not differ materially from expectation. According to Russell[42*] nitrogenous nutrients affect the vegetative growth and, if present in excessive amounts, retard ripening. Phosphorus, on the other hand, promotes growth of the roots during the early life of the plant, but later on it hastens the ripening process. Potash exerts an influence on the vigor and general health of the plant; it is intimately connected with photosynthesis and translocation of carbohydrates; and it influences the formation and especially the weight of grain. Potassium-starved plants are not only stunted in growth in the same way that plants are that lack nitrogen and phosphorus, but they may even fail to reach maturity. Beyond this, potash seems to have little effect on maturity.

The data on soil treatments in relation to maturity have been summarized briefly in Table 36. Quantities therein represent the mean number of days required for sweet corn on each treated plot to reach 75 percent of full silking compared with the respective adjacent checks. Negative quantities indicate that the sweet corn receiving the treatment matured earlier than the check, and positive quantities, later. The value of silk counts as an index of maturity has already been pointed out (page 356).

TABLE 36.—EFFECT OF SOIL TREATMENTS ON MATURITY AS INDICATED BY NUMBER OF DAYS SILKING WAS RETARDED[a] OR ADVANCED IN COMPARISON WITH THE RESPECTIVE CHECKS

(Negative numbers indicate days earlier than adjacent checks; positive numbers indicate days later than adjacent checks.)

NITROGEN SERIES

Potash increasing[a]	(A) Nitrogen increasing			
	00x	10x	20x	40x
x00	.....	.08	2.08	.08
x01	2.25	2.00	1.33	− .83
x02	.33	− .33	1.67	.58
x04	.92	1.25	− .25	1.33

Phosphorus increasing[a]	(B) Nitrogen increasing			
	0x1	1x1	2x1	4x1
x01	2.25	2.00	1.33	− .83
x11	− .67	− .83	− .83	−2.67
x21	−3.33	−4.67	−3.67	−1.92
x41	−5.33	−4.42	−4.25	−3.25

Phosphorus increasing	(C) Nitrogen increasing			
	0x2	1x2	2x2	4x2
x02	.33	− .33	1.67	.58
x12	−2.25	−2.92	−1.92	−1.58
x22	−2.41	−3.67	−4.08	−2.83
x42	−5.08	−4.92	−2.50	.33

Phosphorus increasing	(D) Nitrogen increasing			
	0x4	1x4	2x4	4x4
x04	.92	1.25	− .25	1.33
x14	−3.58	−3.92	− .75	−3.17
x24	−3.17	−3.50	−2.73	−3.75
x44	−5.00	−5.17	−3.33	.67

Phosphorus increasing	(E) Nitrogen increasing			
	0x0	1x0	2x0	4x0
x00	.....	.08	2.08	.08
x10	−2.92	−1.08	.42	−1.17
x20	−1.67	−3.50	−2.67	−4.33
x40	−2.33	−4.92	−4.45	−3.17

Potash increasing	(F) Nitrogen increasing			
	01x	11x	21x	41x
x10	−2.92	−1.08	.42	−1.17
x11	− .67	− .83	− .83	−2.67
x12	−2.25	−2.92	−1.92	−1.58
x14	−3.58	−3.92	− .75	−3.17

Potash increasing	(G) Nitrogen increasing			
	02x	12x	22x	42x
x20	−1.67	−3.50	−2.67	−4.33
x21	−3.33	−4.67	−3.67	−1.92
x22	−2.41	−3.67	−4.08	−2.83
x24	−3.17	−3.50	−2.73	−3.75

Potash increasing	(H) Nitrogen increasing			
	04x	14x	24x	44x
x40	−2.33	−4.92	−4.45	−3.17
x41	−5.33	−4.42	−4.25	−3.25
x42	−5.08	−4.92	−2.50	.33
x44	−5.00	−5.17	−3.33	.67

PHOSPHORUS SERIES

Potash increasing	(I) Phosphorus increasing			
	00x	01x	02x	04x
0x0	.....	−2.92	−1.67	−2.33
0x1	2.25	− .67	−3.33	−5.33
0x2	.33	−2.25	−2.41	−5.08
0x4	.92	−3.58	−3.17	−5.00

Potash increasing	(J) Phosphorus increasing			
	10x	11x	12x	14x
1x0	.08	−1.08	−3.50	−4.92
1x1	2.00	− .83	−4.67	−4.42
1x2	− .33	−2.92	−3.67	−4.92
1x4	1.25	−3.92	−3.50	−5.17

Potash increasing	(K) Phosphorus increasing			
	20x	21x	22x	24x
2x0	2.08	.42	−2.67	−4.45
2x1	1.33	− .83	−3.67	−4.25
2x2	1.67	−1.92	−4.08	−2.50
2x4	− .25	− .75	−2.73	−3.33

Potash increasing	(L) Phosphorus increasing			
	40x	41x	42x	44x
4x0	.08	−1.17	−4.33	−3.17
4x1	− .83	−2.67	−1.92	−3.25
4x2	.58	−1.58	−2.83	.33
4x4	1.33	−3.17	−3.75	.67

[a]The sections in this table may be read either vertically or horizontally. Read either way, treatment code numbers are obtained by replacing the symbol for the changing dosage (x) by the corresponding figure in the code designation at the top of the columns or in the column at the left.

NITROGEN IN RELATION TO MATURITY

Nitrogen Alone.—Increasing the nitrate dosages did not seem to affect maturity materially, altho there was a tendency for it to retard ripening (Section A, Table 36).

Nitrogen Varying, Phosphorus Constant.—Increasing the amounts of nitrate in combination with a single dosage of phosphorus (Set *x*10) seemed to retard maturity slightly (Section E, Table 36). On the other hand, nitrate seemed to hasten maturity when used in combination with 64 or 128 pounds P_2O_5 per acre.

Nitrogen Varying, Potash Constant.—With the single potash dosage constant, increasing dosages of nitrate appeared to hasten maturity slightly (Set *x*01), but with heavier dosages of potash constant, nitrate gave variable results (Section A, Table 36).

Nitrogen Varying, Phosphorus and Potash Constant.—(1) K_2O 25 pounds per acre constant (Section B, Table 36). In Set *x*11 there was a very slight tendency for nitrate to hasten maturity. With increased phosphorus (Sets *x*21 and *x*41), nitrate in the heavier dosages exercised a slightly retarding effect.

(2) K_2O 50 pounds per acre constant (Section C, Table 36). In the set containing the low phosphorus dosage (*x*12) nitrate had a slightly retarding effect, which became more pronounced in Set *x*42. With 64 pounds of phosphorus per acre (Set *x*22) nitrate had a tendency to hasten maturity.

(3) K_2O 100 pounds per acre constant (Section D, Table 36). Nitrate appeared relatively ineffective with dosages of 32 and 64 pounds phosphorus per acre constant, but had a retarding effect with the quadrupled dosage of phosphorus constant.

(4) P_2O_5 32 pounds per acre constant (Section F, Table 36). Apparently nitrate in these combinations was not particularly effective in influencing maturity. In Set *x*11 nitrate hastened maturity to some extent, but in Sets *x*12 and *x*14 it appeared to retard ripening slightly.

(5) P_2O_5 64 pounds per acre constant (Section G, Table 36). In Set *x*21 a single dosage of nitrate promoted maturity by more than a day, and in Set *x*22 the double dosage of nitrate was most effective. In Set *x*24, however, the high potash dosage appeared to prevent nitrate from being particularly effective.

(6) P_2O_5 128 pounds per acre constant (Section H, Table 36). With the high phosphorus dosage constant, nitrate in all dosages exercised a definite retarding effect upon maturity.

PHOSPHORUS IN RELATION TO MATURITY

Phosphorus Alone.—The lowest dosage appeared to be just as efficacious as the highest in hastening maturity (Section I, Table 36).

Phosphorus Varying, Potash Constant.—Added increments of phosphorus exerted a very strong effect upon maturity irrespective of the potash in the combination (Section I, Table 36). The heaviest phosphorus treatments advanced maturity very considerably.

Phosphorus Varying, Nitrogen Constant.—Increasing phosphorus in relation to the three nitrogen constants hastened maturity greatly (Section E, Table 36).

Phosphorus Varying, Nitrogen and Potash Constant.—(1) Nitrogen 7.5 pounds per acre constant (Section J, Table 36). Phosphorus exerted a very strong effect toward earlier maturity regardless of the potash constant.

(2) Nitrogen 15 pounds per acre constant (Section K, Table 36). The effects were similar to those obtained when 7.5 pounds nitrogen per acre were constant.

(3) Nitrogen 30 pounds per acre constant (Section L, Table 36). With high nitrogen and low potash constant, phosphorus, in increasing dosages, hastened maturity, but with the double dosage of potash constant, the heaviest phosphorus dosage retarded maturity slightly. The same was true with quadruple potash constant.

(4) K_2O 25 pounds per acre constant (Section B, Table 36). With low potash, increasing the phosphorus dosage hastened maturity regardless of the amount of nitrogen used.

(5) K_2O 50 pounds per acre constant (Section C, Table 36). With double potash and low nitrogen constant, maturity was advanced as phosphorus increased (Set 1*x*2), but in Set 2*x*2 the earliest maturity occurred with Treatment 222. In Set 4*x*2 maturity was progressively earlier only as far as Treatment 422.

(6) K_2O 100 pounds per acre constant (Section D, Table 36). In Set 1*x*4 maturity became progressively earlier in relation to the amount of phosphorus. This also occurred in Set 2*x*4 but maturity was not advanced so greatly. In Set 4*x*4 Treatment 424 gave the earliest maturity, but Treatment 444 definitely retarded it.

POTASH IN RELATION TO MATURITY

Potash Alone.—The low potash treatment retarded maturity more than two days, but with increasing dosages this retarding effect was not so marked (Section A, Table 36).

Potash Varying, Nitrogen Constant.—Maturity was definitely delayed by most of these treatments (Section A, Table 36). There was, however, no definite trend.

Potash Varying, Phosphorus Constant.—In Set 01*x* Treatment 014, having the heaviest potash dosage, was the only one giving earlier maturity than Treatment 010 (Section I, Table 36). In Set 02*x* the treatment containing the single dosage of potash was more effective than the others. The same occurred in Set 04*x*.

Potash Varying, Nitrogen and Phosphorus Constant.—(1) Nitrogen 7.5 pounds per acre constant (Section J, Table 36). Increasing dosages of potash were to some extent effective in promoting maturity.

(2) Nitrogen 15 pounds per acre constant (Section K, Table 36). In Set 21*x* potash advanced maturity progressively up to Treatment 212, and in Set 22*x* as far as Treatment 222. In Set 24*x* potash retarded maturity slightly compared with Treatment 240.

(3) Nitrogen 30 pounds per acre constant (Section L, Table 36). Potash advanced maturity in Set 41*x*, but was ineffective in Set 42*x*. In Set 44*x* all dosages of potash except the smallest (Treatment 441) retarded maturity.

(4) P_2O_5 32 pounds per acre constant (Section F, Table 36). With low phosphorus, potash advanced maturity progressively in Set 11*x*, but in Set 21*x* Treatment 212 hastened ripening most. In Set 41*x* potash affected maturity more strongly, the high treatment hastening maturity considerably.

(5) P_2O_5 64 pounds per acre constant (Section G, Table 36). In Set 12*x* Treatment 121 advanced maturity most, while in Set 22*x* Treatment 222 was best. Potash was not effective in Set 42*x*.

(6) P_2O_5 128 pounds per acre constant (Section H, Table 36). Potash exerted a very slight effect in Set 14*x*, and in Set 24*x* there was some retardation due to potash. However, in Set 44*x* potash retarded maturity very definitely, when applied in the higher dosages.

DISCUSSION OF INFLUENCE OF FERTILIZERS ON MATURITY

Nitrate of soda was not at all consistent in its influence on the maturity of sweet corn. Nitrate alone had virtually no effect, but in combination with sufficient phosphorus, it hastened maturity. Added in increasing amounts to various potash constants, it hastened maturity slightly when a single dosage of potash was held constant, but gave variable results with heavier dosages of potash. In complete fertilizers the influence of nitrate was determined to a large extent by the nature

of the combination. In general, nitrate was least effective in combinations with quadruple phosphorus and quadruple potash dosages.

Of the three fertilizer components, phosphorus had the most distinct effect on maturity. The results were similar to those obtained by Buie, Currin, Kyzer, and Warner[12*] with cotton. Used alone, in combination with potash, or in combination with nitrogen, phosphorus hastened maturity considerably. In complete fertilizers, phosphorus advanced maturity rather consistently, except where quadruple dosages were used with the heavier dosages of nitrogen and potash.

Maturity was retarded by potash used alone or in combination with nitrogen, but was advanced apparently by the single dosage of potash combined with double or quadruple dosages of phosphorus. In complete fertilizers, potash hastened maturity only in certain combinations; as the constants of nitrogen increased, potash was effective only where low phosphorus entered into the combination. Fertilizers containing both quadruple nitrogen and quadruple phosphorus dosages retarded maturity progressively with increased dosages of potash. On the other hand, in combinations containing quadruple nitrogen and single phosphorus, potash effectively advanced maturity. In general, potash used in complete fertilizers had an uneven effect on maturity.

SELECTION OF OPTIMUM TREATMENT

At the outset of this study the authors held the opinion that sweet corn is rather critical in its plant-food requirements, and that it responds well to fertilizers only when the proper ratios of nitrogen, phosphorus and potash are applied. That this assumption was correct has been shown repeatedly by the large increases in yield secured in these experiments when certain combinations of the nutrient elements were used, and failure to secure significant increases or even any increases at all when other combinations were used.

Upon the basis of relative efficiencies of the three nutrient elements, six combinations were found to be especially significant*—those of Set 12x from the standpoint of reciprocal efficiencies of nitrogen and phosphorus, Set 1x2 from the standpoint of nitrogen and potassium, and Sets x14, x22, x41 with reference to phosphorus and potassium, the last two elements apparently bearing an inverse relationship in regard to reciprocal efficiencies and consequently offering a wider range of significant combinations. From these combinations Treatments 041, 121, 122, and 114 seem to meet the optimum requirements more closely

*See discussions of possible optimum treatments on pages 403 and 413.

than any of the remaining 59 treatments. As these ratios are evidently quite diverse and as they differ materially in the relative efficiency of the various elements, there remains the possibility of further selection within this group. The four treatments are compared in Tables 37 and 38, in the latter of which certain additional treatments are included in order to facilitate the comparisons.

Treatment 041, having a significant phosphorus efficiency and a potash efficiency which is comparatively high but not statistically significant, was probably the best of the ratios containing minerals only. Treatments 014, 021, 022 and 042 were all very much inferior. One fundamental objection which may be raised against Treatment 041, however, is that of high cost because of the large quantity involved—800 pounds of 0-16-3 per acre. One possibility of avoiding this high cost and at the same time of retaining the ratio would be to cut the application in half. The effect of such a treatment is not directly ascertainable from the results of these experiments, but may be determined indirectly thru the efficiencies of Treatments 021 and 020, which are equivalent respectively to half of Treatments 042 and 040. The mean efficiency of Treatment 021 was 12.15 ± 2.4 and that of Treatment 020 was 10.02 ± 2.7 (Table 38). The mean efficiency of Treatment 02½ (half of Treatment 041) would probably lie either between 10.02 and 12.15 or very close to them. On a basis of yield increases, Treatment 02½ would probably lie between 10.02 ± 2.7 and 18.75 ± 4.3, the percentage increases of Treatments 020 and 021 respectively.

In view of the foregoing relationships the authors conclude that, altho applications of 800 pounds of 0-16-3 per acre gave substantial increases in yield, it is probable that when smaller applications are made, 0-16-6 will give somewhat better returns. Mineral applications having more than 6 percent potash are not recommended unless nitrate also is added.

Treatment 121, altho it gave good results, has several inherent weaknesses. It has a slightly negative potash efficiency and, in addition, the low nitrogen efficiency common to all of the types of mixtures represented by Set $1x1$. Its actual mean efficiency, 22.71 ± 3.7 (Table 37), is lower, but not significantly lower, than that of Treatment 122 or 144. This ratio is equivalent to 400 pounds of a 0-16-6 ferilizer plus 50 pounds of nitrate per acre. It is not recommended so highly as is Treatment 122.

Treatment 114, with a mean actual efficiency of 26.69 ± 3.8 (Table 37) was superior to either Treatment 121 or 041 despite the low mean nitrogen efficiencies of the $11x$ and $1x4$ types of mixtures. In phos-

TABLE 37.—EFFICIENCY OF THE SEPARATE ELEMENTS AS COMBINED IN THE FOUR TREATMENTS (041, 121, 122, 114) SELECTED AS PROBABLY APPROACHING THE OPTIMUM MORE CLOSELY THAN OTHERS

Element measured	Influencing element	Treatment 041		Treatment 121		Treatment 122		Treatment 114	
		Set	Factor	Set	Factor	Set	Factor	Set	Factor
Mean efficiency factors of elements in sets that included the above treatments									
Nitrogen	Phosphorus	...	.....	12x	17.58 ± 3.4	12x	17.58 ± 3.4	11x	3.20 ± 3.2
	Potash	...	.....	1x1	.70 ± 3.4	1x2	11.44 ± 3.7	1x4	6.12 ± 3.7
Phosphorus	Nitrogen	04x	35.35 ± 2.8	12x	37.17 ± 3.7	12x	37.17 ± 3.7	11x	26.17 ± 3.3
	Potash	x41	33.12 ± 3.1	x21	29.67 ± 3.2	x22	31.84 ± 3.4	x14	29.86 ± 3.6
Potash	Nitrogen	0x1	2.25 ± 2.6	1x1	−3.32 ± 3.5	1x2	11.00 ± 3.8	1x4	10.84 ± 3.6
	Phosphorus	x41	6.71 ± 3.3	x21	−.48 ± 3.4	x22	3.88 ± 3.4	x14	16.59 ± 3.7
Efficiency factor of each nutrient element in the four optimum treatments[a]									
Nitrogen	.....	...	.....	...	15.72 ± 6.4	...	25.95 ± 9.3	...	10.92 ± 7.4
Phosphorus	.....	...	46.39 ± 5.5	...	46.88 ± 6.8	...	42.58 ± 9.4	...	43.24 ± 6.4
Potash	.....	...	17.96 ± 6.2	...	5.54 ± 6.1	...	15.54 ± 9.0	...	25.92 ± 5.8
Mean	.....	...	21.45 ± 2.8[b]	...	22.71 ± 3.7	...	28.02 ± 5.3	...	26.69 ± 3.8

[a]Data taken from Table 40, Appendix.
[b]Nitrogen with a value of zero is included in the mean, but if only phosphorus and potash are averaged, the mean is 32.32 ± 4.1.

phorus efficiency the 11x and x14 types rank very well, and in potash efficiency they are very much higher than any of the others of the group under consideration. The amount of potash and phosphorus in Treatment 114 is equivalent to 400 pounds of 0-8-24 plus 50 pounds of sodium nitrate per acre. This ratio differs so widely from any of the other types showing good performance, that the authors do not recommend it for commercial use unless local tests show that it is better than some of the others.

Treatment 122 was, in general, the best of the four optimum treatments (Table 37). The nitrogen efficiency in the 12x and 1x2 types of mixtures is considerably higher than in either of the other two combinations under consideration. The actual nitrogen efficiency of Treatment 122 (25.95 ± 9.3) is much higher and more nearly significant than that of Treatment 121 or 114. In mean phosphorus efficiency the 12x and x22 types of treatments are about equal or superior to any of the others, and this relationship also holds for the actual efficiency. The mean potash efficiencies of the 1x2 and x22 types are not as high as in the 1x4 and x14 types, and the actual efficiency (15.54 ± 9.0) is not significant.

Thus, altho not one of the four treatments is ideal in all respects, Treatment 122 is undoubtedly superior in general to the others. Because it was high in efficiency, gave much better results than the com-

TABLE 38.—YIELD INCREASES AND EFFICIENCIES OF RECOMMENDED TREATMENTS, AND YIELD INCREASES AND EFFICIENCIES OF SIMILAR BASAL TREATMENTS WITHOUT THE SIDE-DRESSING OF NITROGEN[a]

Code No. of treatment	Phosphorus-potassium applications broadcast		Sodium side-dressed	Increase in weights of marketable ears	Mean efficiency
	Commercial formula (N–P–K)	Amount per acre			
		lbs.	*lbs.*	*perct.*	*perct.*
014	0–8–24	400	...	27.62 ± 5.4	9.68 ± 3.2
114	0–8–24	400	50	38.54 ± 5.1	26.69 ± 3.8
021	0–16–6	400	...	18.75 ± 4.3	12.15 ± 2.4
121	0–16–6	400	50	34.47 ± 4.7	22.71 ± 3.7
022	0–16–12	400	...	18.52 ± 4.6	8.46 ± 2.4
122	0–16–12	400	50	44.47 ± 8.1	28.02 ± 5.3
041	0–16–3	800	...	37.41 ± 4.8	21.45 ± 2.8
141	0–16–3	800	50	32.76 ± 6.3	14.39 ± 5.0
042	0–16–6	800	...	37.28 ± 4.5	17.83 ± 2.6
040	0–16–0	800	...	19.45 ± 4.0	19.45 ± 4.0
020	0–16–0	400	...	10.02 ± 2.7	10.02 ± 2.7

[a]The odds for each treatment are greater than 30:1.

bination of minerals alone in Treatment 041, and is one of the smaller applications, the authors consider it to be the best of the 63 treatments. Treatment 122 is equivalent to 400 pounds per acre of an 0-16-12 fertilizer plus 50 pounds per acre of sodium nitrate side-dressed. As mentioned previously, nitrate of soda should be used only as a side dressing made from 30 to 60 days after planting. In these experiments the nitrate was applied by hand around each hill, but in commercial practice, since it would be applied in strips to one or both sides of the row, more than 50 pounds per acre would undoubtedly be required in obtaining equivalent results.

Without exception, all the fertilizer treatments recommended above hasten the maturing of sweet corn from three to five days. This is an important consideration, not so much because an additional margin is given against early fall frosts as because the planting season may be extended to almost a week later in the spring.

SUMMARY

Data from six years' experiments have been presented and evidence offered that the three major plant-food elements—nitrogen, phosphorus, and potassium—interact in a manner which affects markedly the yield and maturity of sweet corn. The more important points brought out in this study are the following:

Yield Increases

Nitrogen Efficiency.—The effectiveness of sodium nitrate as a side dressing was dependent upon the amount of nitrate used, the ratio of other minerals used, the type of rotation practiced, and the time at which the sodium nitrate was applied:

1. When sodium nitrate was used as a side dressing without an accompanying basal treatment of one or both of the mineral salts, the increases in yield were inconsistent, and nitrogen efficiency varied around the zero point.

2. When the basal mineral treatment consisted of phosphorus, increases in yield were more consistent than when either nitrogen or phosphorus was used alone. The maximum efficiency of nitrogen used with phosphorus was associated with 50 pounds of sodium nitrate and 64 pounds of P_2O_5 per acre.

3. When the basal mineral treatment consisted of potash, increases in yield were very inconsistent, probably because of a deficiency of available phosphorus in the soil.

4. Sodium nitrate as a supplement to combinations of phosphorus and potash gave better results than as a supplement to either mineral alone. Maximum nitrogen efficiency was associated with a treatment composed of 50 pounds of sodium nitrate side-dressed as a supplement to 64 pounds of P_2O_5 and 50 pounds of K_2O per acre. Nitrogen efficiency decreased when sodium nitrate was applied in quantities of more than 50 pounds per acre unless the basal potash dosage was reduced greatly or omitted.

5. Nitrogen gave better results on soils having sufficient organic matter supplied by plowing under legumes than on soils where sweet corn was grown without clover in the rotation.

Phosphorus Efficiency.—The usefulness of superphosphate as a fertilizer ingredient also was affected by the ratios of the other minerals used in the combinations, and by the type of rotation maintained:

1. Small dosages of superphosphate applied alone gave larger increases in yield than heavier dosages applied alone.

2. Combinations of phosphorus and nitrogen gave considerably larger yields than were obtained from phosphorus alone. The maximum efficiency of phosphorus when used with nitrogen was associated with an application of 50 pounds of sodium nitrate per acre.

3. Combinations of phosphorus and potash also gave better results than did phosphorus alone. The efficiency of phosphorus in these combinations increased as the amount of phosphorus used was increased.

4. In complete fertilizers adequate amounts of phosphorus were essential. The maximum efficiency of phosphorus was reached in combinations containing 50 pounds of sodium nitrate per acre supplementing 64 pounds of P_2O_5 per acre. Phosphorus and potash had a distinctly inverse relationship, on the basis of marketable ears, whereby phosphorus maintained an equivalent efficiency when the smallest phosphorus dosage was combined with the heaviest potash dosage or the heaviest phosphorus dosage with the smallest potash dosage.

5. Phosphorus gave uniformly better results when clover was used in the rotation than when it was not included.

The increases in phosphorus efficiency in combinations containing both nitrogen and potash indicated that the two other elements were important in increasing the availability of phosphorus to the plant.

Potash Efficiency.—The role of potash as a fertilizer ingredient was strongly dependent upon the ratio of the other minerals used with it:

1. Muriate of potash used alone failed to increase yields appreciably, and in many instances appeared to be injurious.

2. Combinations of potash and nitrogen gave highly variable results, indicating that phosphorus was the limiting factor. In efficiency, potash and nitrogen gave evidence of being in inverse relationship to each other.

3. Combinations of potash and phosphorus gave substantial increases in yield; the efficiency of potash increased with increasingly larger applications. Potash and phosphorus also showed a tendency toward an inverse relationship.

Advance in Maturity of Crops

Nitrogen Action.—When used alone, nitrogen had no consistent influence on maturity. Used in combination with adequate phosphorus, it hastened maturity. Combinations of nitrogen and potash advanced maturity only to a slight extent and only in combinations containing the single dosage of potash. In complete fertilizers nitrogen gave variable results, being least effective in advancing maturity in those combinations that contain the maximum dosages of both phosphorus and potash.

Phosphorus Action.—Much more than either nitrogen or potash, phosphorus hastened maturity. Phosphorus proved least effective when applied in maximum dosages in combinations containing some of the larger amounts of nitrogen and potash.

Potassium Action.—Potash used alone or in combination with nitrogen retarded maturity. Small amounts of potash combined with adequate dosages of phosphorus advanced maturity very materially. Potash forming part of a complete fertilizer did not give consistent results either in hastening or in retarding maturity.

RECOMMENDATIONS

A few general rules have been evolved in the application of fertilizers to soils of the dark silt loam prairie type used in these experiments which should be taken into consideration before specific recommendations for fertilizing sweet corn are made. Treatments of single fertilizer salts should usually be avoided because their efficiency values are low and sometimes even negative. Mixtures of two salts containing nitrogen and phosphorus or phosphorus and potash give good results if the proper ratios are used.

Upon the basis of the results obtained in this study, the following suggestions for fertilizing sweet corn are presented:

1. Use a rotation including legumes in order to secure maximum responses from commercial fertilizers.

2. Where nitrogen is omitted, apply 800 pounds of an 0-16-3 fertilizer per acre broadcast.

3. If it is desired to apply less than 800 pounds of fertilizer (without nitrogen) per acre, an 0-16-6 combination will probably prove superior to 0-16-3.

4. Mineral fertilizers applied without nitrogen should contain not more than 6 percent potash.

5. For consistent responses with three-element fertilizer combinations, apply 400 pounds of 0-16-12 supplemented by 50 pounds of side-dressed sodium nitrate per acre (Treatment 122). This treatment, of all the 63 investigated, is apparently the best.

6. Under some conditions the 0-16-12 analysis mentioned above may possibly be reduced with advantage to 0-16-6, but the amount of nitrate used as a side-dressing should not be changed. (Treatment 121).

7. An application of 400 pounds of an 0-8-24 fertilizer, plus side-dressed sodium nitrate at the rate of 50 pounds per acre (Treatment 114), may prove profitable under some conditions.

8. Nitrate of soda should be applied 30 to 60 days after the corn is planted.

The quantities of sodium nitrate recommended here are based on applications made by hand around the hill.[a] If machines are used to apply this salt in continuous strips, the amounts per acre will probably have to be increased.

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[a]Fertilizer recommendations which have been made as a result of these experiments, but previous to their publication here, were limited to phosphorus-potash combinations. Such mixtures have given excellent results in many instances, especially when applied around the hill with the corn-planter fertilizer attachment. A considerable portion of the sweet-corn acreage in the northern part of Illinois is being fertilized with 0-16-6 applied around the hill at the rate of about 100 pounds an acre. This is equivalent to one-fourth of the quantity of salts contained in Treatment 021. A good many efforts have been made by the senior author to introduce complete fertilizer analyses, but without success, owing to the fact that nitrogen, even in the form of sodium nitrate, applied around the hill *at the time of planting* frequently seems to exercise a depressive effect on yields. This statement is supported by considerable experimental evidence which is not reported here. The important point to remember is that nitrogen used as a side-dressing applied later may react quite differently from nitrogen forming part of a complete analysis and applied at the time of planting. (For further discussion of this subject see Ill. Agr. Exp. Sta., 45th Ann. Rpt., pp. 218-220.)

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APPENDIX

TABLE 39.—MEAN YIELDS AND YIELD INCREASES ON TREATED PLOTS OVER RESPECTIVE ADJACENT CHECK PLOTS[a]

Treatment	Yield from treated plot	Yield from check	Increase with treatment	Odds	Percentage increase	Dev. / P. E.
	Number of marketable ears per acre					
001	6 273	6 842	−569 ± 144	73:1	−8.32 ± 2.1	3.9
002	5 970	5 977	−7 ± 92	<1:1	− .12 ± 1.5	.1
004	6 123	5 977	146 ± 162	3:1	2.44 ± 2.7	.9
010	7 124	5 728	1396 ± 283	224:1	24.37 ± 5.0	4.9
011	6 595	5 728	867 ± 230	57:1	15.14 ± 4.0	3.8
012	7 041	5 970	1071 ± 287	57:1	17.94 ± 4.8	3.7
014	7 582	5 970	1611 ± 328	224:1	26.98 ± 5.5	4.9
020	7 736	6 987	749 ± 258	21:1	10.72 ± 3.7	2.9
021	8 132	6 987	1145 ± 354	31:1	16.39 ± 5.1	3.2
022	8 391	6 915	1476 ± 251	666:1	21.34 ± 3.6	5.9
024	8 082	6 895	1187 ± 190	948:1	17.22 ± 2.8	6.2
040	7 080	5 950	1130 ± 225	259:1	18.99 ± 3.8	5.0
041	7 586	5 714	1872 ± 197	>9999:1	32.76 ± 3.4	9.5
042	7 772	5 851	1921 ± 229	>9999:1	32.83 ± 3.9	8.4
044	7 960	5 765	2195 ± 319	1932:1	38.07 ± 5.5	6.9
100	5 440	5 176	264 ± 202	4:1	5.10 ± 3.9	1.3
101	5 229	6 176	−946 ± 417	10:1	−15.32 ± 6.7	2.3
102	6 603	6 480	123 ± 170	2:1	1.90 ± 2.7	.7
104	6 095	6 223	−128 ± 230	2:1	−2.06 ± 3.4	.6
110	6 987	6 221	766 ± 152	259:1	12.31 ± 2.5	5.0
111	6 933	6 275	658 ± 111	666:1	10.49 ± 1.8	5.9
112	7 398	5 664	1734 ± 244	2799:1	30.61 ± 4.3	7.1
114	6 903	5 139	1764 ± 234	3332:1	34.32 ± 4.6	7.5
120	7 316	5 706	1610 ± 184	>9999:1	28.22 ± 3.2	8.8
121	7 565	5 702	1862 ± 275	1799:1	32.66 ± 4.8	6.8
122	7 883	5 564	2318 ± 353	1444:1	41.66 ± 6.3	6.6
124	7 406	5 499	1908 ± 342	494:1	34.70 ± 6.2	5.6
140	7 947	6 189	1758 ± 377	169:1	28.40 ± 6.0	4.7
141	8 164	6 576	1588 ± 334	188:1	24.15 ± 5.0	4.8
142	8 307	6 576	1731 ± 289	714:1	26.32 ± 4.4	6.0
144	8 280	5 741	2539 ± 393	1221:1	44.22 ± 6.8	6.5
200	5 578	5 751	−172 ± 194	2:1	−2.99 ± 3.3	.9
201	6 052	6 548	−496 ± 150	27:1	−7.57 ± 2.3	3.3
202	5 665	5 918	−253 ± 295	2:1	−4.28 ± 4.8	.9
204	5 854	5 627	227 ± 345	2:1	4.03 ± 5.8	.7
210	6 103	5 980	123 ± 283	1:1	2.06 ± 5.2	.4
211	6 666	5 830	835 ± 250	35:1	14.32 ± 4.3	3.3
212	7 103	5 507	1596 ± 294	400:1	28.98 ± 5.4	5.4
214	7 164	5 787	1377 ± 274	259:1	23.79 ± 4.8	5.0
220	7 196	5 677	1519 ± 248	860:1	26.76 ± 4.4	6.1
221	7 849	6 169	1680 ± 268	989:1	27.23 ± 4.3	6.3
222	7 996	6 438	1557 ± 297	323:1	24.18 ± 4.6	5.2
224	8 017	7 079	938 ± 351	14:1	13.25 ± 4.9	2.7
240	8 568	6 987	1582 ± 244	770:1	22.64 ± 3.5	6.5
241	8 418	6 884	1534 ± 330	169:1	22.28 ± 4.8	4.6
242	8 390	6 932	1458 ± 455	30:1	21.03 ± 6.6	3.2
244	8 861	7 425	1436 ± 204	2532:1	19.34 ± 2.8	7.0
400	6 899	7 282	−384 ± 173	9:1	−5.27 ± 2.4	2.2
401	7 146	6 304	843 ± 143	399:1	13.37 ± 2.3	5.9
402	6 489	6 559	−70 ± 289	<1:1	−1.07 ± 5.4	.2
404	7 085	7 179	−94 ± 273	1:1	−1.31 ± 4.4	.3
410	7 066	6 209	857 ± 296	21:1	13.80 ± 4.8	2.9
411	7 166	6 344	822 ± 285	21:1	12.96 ± 4.5	2.9
412	7 250	6 554	696 ± 203	40:1	10.62 ± 3.1	3.4
414	7 583	6 046	1537 ± 382	78:1	25.42 ± 6.4	4.0
420	8 004	6 048	1956 ± 295	1555:1	32.34 ± 4.9	6.6
421	7 226	6 048	1178 ± 352	35:1	19.48 ± 5.7	3.4
422	7 644	5 832	1812 ± 143	>9999:1	31.07 ± 2.4	12.7
424	7 788	5 832	1956 ± 173	>9999:1	33.54 ± 3.0	11.3
440	8 201	7 157	1044 ± 259	78:1	14.59 ± 3.6	4.0
441	8 615	7 157	1458 ± 174	>9999:1	20.37 ± 2.4	8.4
442	8 617	7 873	744 ± 227	33:1	9.45 ± 2.9	3.3
444	7 902	7 655	246 ± 187	4:1	3.21 ± 2.5	1.3

[a]The increases in yield shown in the fourth column are averages of annual yield differences rather than differences between the averages shown in the second and third columns.

TABLE 39.—MEAN YIELDS AND YIELD INCREASES ON TREATED PLOTS OVER RESPECTIVE ADJACENT CHECK PLOTS—*Continued*

Treatment	Yield from treated plot	Yield from check	Increase with treatment	Odds	Percentage increase	Dev. / P. E.
	Tons of marketable ears per acre					
001	1.958	2.150	−.193 ± .058	33:1	−8.98 ± 2.7	3.3
002	1.875	1.844	.030 ± .034	2:1	1.63 ± 1.6	0.9
004	1.911	1.844	.066 ± .058	3:1	3.58 ± 3.2	1.1
010	2.156	1.754	.397 ± .084	179:1	22.63 ± 4.8	4.7
011	1.998	1.754	.244 ± .070	43:1	13.91 ± 4.0	3.5
012	2.218	1.879	.338 ± .095	46:1	17.99 ± 5.0	3.6
014	2.398	1.879	.519 ± .102	276:1	27.62 ± 5.4	5.1
020	2.459	2.235	.224 ± .060	57:1	10.02 ± 2.7	3.7
021	2.654	2.235	.419 ± .094	132:1	18.75 ± 4.3	4.4
022	2.617	2.208	.409 ± .101	83:1	18.52 ± 4.6	4.0
024	2.596	2.139	.457 ± .072	989:1	21.36 ± 3.4	6.3
040	2.229	1.866	.363 ± .076	198:1	19.45 ± 4.0	4.8
041	2.472	1.799	.673 ± .086	4999:1	37.41 ± 4.8	7.8
042	2.516	1.832	.683 ± .082	>9999:1	37.28 ± 4.5	8.3
044	2.561	1.784	.776 ± .115	1799:1	43.50 ± 6.5	6.7
100	1.667	1.580	.087 ± .082	3:1	5.51 ± 5.0	1.1
101	1.637	1.869	−.232 ± .124	7:1	−12.41 ± 6.5	1.9
102	1.990	1.953	.037 ± .095	1:1	1.89 ± 4.7	0.4
104	1.908	2.002	−.094 ± .080	3:1	−4.70 ± 3.9	1.2
110	2.150	1.909	.241 ± .053	151:1	12.62 ± 2.7	4.6
111	2.140	1.962	.178 ± .068	16:1	9.07 ± 3.5	2.6
112	2.320	1.722	.598 ± .092	1221:1	34.73 ± 5.3	6.5
114	2.200	1.588	.612 ± .080	3332:1	38.54 ± 5.1	7.6
120	2.345	1.818	.526 ± .070	3332:1	28.93 ± 3.9	7.5
121	2.442	1.816	.626 ± .086	3332:1	34.47 ± 4.7	7.3
122	2.522	1.745	.776 ± .142	400:1	44.47 ± 8.1	5.5
124	2.242	1.710	.532 ± .090	666:1	31.11 ± 5.3	5.9
140	2.566	1.972	.594 ± .121	224:1	30.12 ± 6.1	4.9
141	2.638	1.987	.651 ± .125	323:1	32.76 ± 6.3	5.2
142	2.784	1.987	.797 ± .115	1932:1	40.11 ± 5.8	6.9
144	2.718	1.747	.971 ± .134	3332:1	55.58 ± 7.7	7.2
200	1.698	1.750	−.051 ± .038	2:1	−2.91 ± 2.2	1.3
201	1.903	2.050	−.147 ± .038	66:1	−7.17 ± 1.8	3.9
202	1.800	1.853	−.054 ± .097	2:1	−2.91 ± 4.8	0.6
204	1.822	1.730	.092 ± .105	2:1	5.32 ± 5.9	0.9
210	1.925	1.834	.091 ± .100	2:1	4.96 ± 5.5	0.9
211	2.092	1.827	.264 ± .092	21:1	14.45 ± 5.0	2.9
212	2.251	1.706	.545 ± .106	293:1	31.95 ± 6.3	5.1
214	2.228	1.781	.447 ± .093	198:1	25.10 ± 5.2	4.8
220	2.267	1.724	.543 ± .083	1332:1	31.50 ± 4.8	6.5
221	2.451	1.858	.593 ± .098	811:1	31.92 ± 5.2	6.1
222	2.595	1.998	.598 ± .102	666:1	29.93 ± 5.2	5.8
224	2.619	2.248	.371 ± .130	17:1	16.50 ± 5.9	2.8
240	2.871	2.222	.648 ± .091	1499:1	29.16 ± 4.1	7.1
241	2.750	2.179	.571 ± .107	354:1	26.20 ± 4.8	5.3
242	2.757	2.194	.563 ± .160	43:1	25.66 ± 7.3	3.5
244	2.904	2.281	.622 ± .070	9999:1	27.27 ± 3.1	8.9
400	2.099	2.206	−.107 ± .057	6:1	−4.85 ± 2.6	1.9
401	2.209	1.882	.327 ± .063	195:1	17.38 ± 3.3	5.2
402	1.933	1.993	−.060 ± .086	2:1	−3.01 ± 4.3	0.7
404	2.185	2.235	−.050 ± .086	2:1	−2.24 ± 3.7	0.6
410	2.225	1.938	.287 ± .095	25:1	14.81 ± 4.9	3.0
411	2.299	1.980	.318 ± .103	27:1	16.06 ± 5.1	3.1
412	2.309	2.060	.250 ± .067	57:1	12.14 ± 3.3	3.7
414	2.471	1.899	.572 ± .130	123:1	30.12 ± 7.0	4.4
420	2.623	1.888	.736 ± .083	>9999:1	38.98 ± 4.4	8.9
421	2.310	1.888	.422 ± .131	31:1	22.35 ± 7.0	3.2
422	2.419	1.832	.587 ± .058	>9999:1	32.04 ± 3.2	10.1
424	2.483	1.832	.651 ± .046	>9999:1	35.53 ± 2.5	14.2
440	2.648	2.289	.360 ± .092	68:1	15.73 ± 4.0	3.9
441	2.860	2.289	.571 ± .063	>9999:1	24.94 ± 2.7	9.1
442	2.878	2.544	.334 ± .080	99:1	13.13 ± 3.1	4.2
444	2.590	2.445	.144 ± .074	7:1	5.89 ± 3.1	1.9

TABLE 39.—MEAN YIELDS AND YIELD INCREASES ON TREATED PLOTS OVER RESPECTIVE ADJACENT CHECK PLOTS—*Concluded*

Treatment	Yield from treated plot	Yield from check	Increase with treatment	Odds	Percentage increase	Dev. / P. E.
	Tons of green fodder per acre					
001	3.243	3.694	−.452 ± .265	6:1	−12.24 ± 7.2	1.7
002	3.355	3.193	.162 ± .108	5:1	5.07 ± 3.4	1.5
004	3.114	3.193	−.078 ± .109	2:1	−2.44 ± 3.5	0.7
010	3.194	2.762	.432 ± .110	73:1	15.64 ± 4.0	3.9
011	3.065	2.762	.303 ± .104	22:1	10.97 ± 3.8	2.9
012	3.428	3.018	.410 ± .131	28:1	13.58 ± 4.4	3.1
014	4.206	3.018	1.188 ± .152	4999:1	39.36 ± 5.0	7.8
020	3.822	3.430	.393 ± .139	19:1	11.46 ± 4.1	2.8
021	4.224	3.430	.795 ± .137	610:1	23.18 ± 4.0	5.8
022	4.280	3.407	.873 ± .180	198:1	25.62 ± 5.3	4.8
024	4.558	3.408	1.150 ± .168	1866:1	33.74 ± 5.0	6.8
040	3.185	3.180	.004 ± .105	<1:1	1.26 ± 31.5	.04
041	3.852	2.911	.940 ± .152	908:1	32.29 ± 5.2	6.2
042	3.782	2.844	.939 ± .162	610:1	33.02 ± 5.7	5.8
044	4.098	2.776	1.322 ± .144	>9999:1	47.62 ± 5.2	9.2
100	2.839	2.587	.252 ± .212	3:1	9.74 ± 8.1	1.2
101	2.973	2.912	.061 ± .226	1:1	2.09 ± 7.0	0.3
102	3.857	3.008	.849 ± .123	1932:1	28.22 ± 4.1	6.9
104	3.386	3.143	.242 ± .170	4:1	7.70 ± 5.5	1.4
110	3.354	2.924	.430 ± .106	83:1	14.71 ± 3.6	4.1
111	3.102	3.158	−.056 ± .087	2:1	−1.77 ± 3.0	0.6
112	3.849	2.704	1.145 ± .144	4999:1	42.34 ± 5.3	8.0
114	3.482	2.562	.920 ± .098	>9999:1	35.91 ± 3.8	9.4
120	3.455	3.033	.422 ± .100	99:1	13.91 ± 3.3	4.2
121	3.920	3.095	.825 ± .177	169:1	26.66 ± 5.7	4.7
122	4.134	3.079	1.056 ± .200	339:1	34.30 ± 6.5	5.3
124	3.974	2.917	1.057 ± .185	553:1	36.24 ± 6.4	5.7
140	3.907	3.174	.733 ± .155	179:1	23.09 ± 4.9	4.7
141	4.202	3.102	1.100 ± .178	948:1	35.46 ± 5.7	6.2
142	4.604	3.102	1.503 ± .138	>9999:1	48.45 ± 4.4	10.9
144	4.726	2.807	1.919 ± .243	4999:1	68.36 ± 8.6	7.9
200	2.447	2.572	−.125 ± .076	5:1	−4.86 ± 3.0	1.6
201	3.031	3.200	−.168 ± .088	7:1	−5.25 ± 2.8	1.9
202	3.058	3.064	−.006 ± .177	<1:1	−0.20 ± 6.6	.03
204	3.315	2.660	.656 ± .159	88:1	24.66 ± 6.0	4.1
210	2.895	2.866	.029 ± .144	1:1	1.01 ± 5.0	0.2
211	3.703	3.366	.338 ± .105	31:1	10.04 ± 3.1	3.2
212	3.494	2.916	.577 ± .185	28:1	19.79 ± 6.4	3.1
214	3.910	3.012	.898 ± .132	1799:1	29.81 ± 4.4	6.8
220	3.160	2.934	.227 ± .133	6:1	7.74 ± 4.6	1.7
221	3.721	2.912	.809 ± .138	638:1	27.78 ± 4.8	5.8
222	4.047	2.918	1.129 ± .136	>9999:1	38.69 ± 4.7	8.3
224	4.765	3.335	1.430 ± .180	2499:1	42.88 ± 5.4	8.0
240	4.502	3.261	1.241 ± .175	1499:1	38.06 ± 5.4	7.1
241	4.287	3.218	1.068 ± .194	431:1	33.20 ± 6.0	5.5
242	4.832	3.434	1.398 ± .228	860:1	40.71 ± 6.7	6.1
244	4.814	3.166	1.648 ± .165	>9999:1	52.05 ± 5.2	10.0
400	3.294	3.348	−.053 ± .084	2:1	−1.58 ± 2.6	0.6
401	3.548	3.042	.506 ± .132	48:1	16.63 ± 4.4	3.8
402	3.190	3.002	.188 ± .139	4:1	6.26 ± 4.5	1.4
404	3.663	3.752	−.089 ± .169	2:1	−2.37 ± 4.7	0.5
410	3.359	3.412	−.053 ± .302	<1:1	−1.55 ± 7.8	0.2
411	3.890	3.296	.595 ± .137	109:1	18.05 ± 4.2	4.3
412	4.256	3.563	.693 ± .180	63:1	19.45 ± 5.1	3.8
414	4.376	3.369	1.007 ± .201	241:1	29.89 ± 6.0	5.0
420	3.942	2.997	.946 ± .183	308:1	31.56 ± 6.1	5.2
421	3.406	2.997	.409 ± .184	10:1	13.65 ± 6.2	2.2
422	3.827	2.831	.995 ± .127	4999:1	35.15 ± 4.5	7.8
424	3.986	2.831	1.155 ± .132	>9999:1	40.80 ± 4.6	8.8
440	4.603	3.644	.959 ± .176	400:1	26.32 ± 4.9	5.4
441	4.914	3.644	1.270 ± .216	666:1	34.85 ± 5.9	5.9
442	5.264	4.324	.940 ± .115	4999:1	21.74 ± 2.6	8.2
444	5.146	4.324	.822 ± .152	369:1	19.01 ± 3.5	5.4

TABLE 40.—EFFICIENCY FACTORS OF THE THREE NUTRIENT ELEMENTS IN THE VARIOUS DOSAGES AND COMBINATIONS

(Calculated on the basis of weights of marketable ears)

Treatment	Increase in yield over adjacent checks	Treatments subtracted[a]			Efficiency factors[b]		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
	perct.				*perct.*	*perct.*	*perct.*
001	−8.98 ± 2.7	...	...	...	.....	.....	−8.98 ± 2.7
002	1.63 ± 1.6	...	...	...	.....	.....	1.63 ± 1.6
004	3.58 ± 3.2	...	...	...	.....	.....	3.58 ± 3.2
010	22.63 ± 4.8	...	...	...	.....	22.63 ± 4.8	.....
011	13.91 ± 4.0	...	001	010	.....	22.89 ± 4.8	−8.72 ± 6.2
012	17.99 ± 5.0	...	002	010	.....	16.36 ± 5.2	−4.64 ± 6.9
014	27.62 ± 5.4	...	004	010	.....	24.04 ± 6.3	4.99 ± 7.2
020	10.02 ± 2.7	...	...	...	.....	10.02 ± 2.7	.....
021	18.75 ± 4.3	...	001	020	.....	27.73 ± 5.1	8.73 ± 5.1
022	18.52 ± 4.6	...	002	020	.....	16.89 ± 4.9	8.50 ± 5.3
024	21.36 ± 3.4	...	004	020	.....	17.78 ± 4.7	11.34 ± 4.3
040	19.45 ± 4.0	...	...	...	.....	19.45 ± 4.0	.....
041	37.41 ± 4.8	...	001	040	.....	46.39 ± 5.5	17.96 ± 6.2
042	37.28 ± 4.5	...	002	040	.....	35.65 ± 4.8	17.83 ± 6.0
044	43.50 ± 6.5	...	004	040	.....	39.92 ± 7.2	24.05 ± 7.6
100	5.51 ± 5.0	...	...	...	5.51 ± 5.0	.....	.....
101	−12.41 ± 6.5	001	...	100	−3.43 ± 7.0	.....	−17.92 ± 8.2
102	1.89 ± 4.7	002	...	100	.26 ± 4.9	.....	−3.62 ± 6.9
104	−4.70 ± 3.9	004	...	100	−8.28 ± 5.0	.....	−10.21 ± 6.3
110	12.62 ± 2.7	010	100	...	−10.01 ± 5.5	7.11 ± 5.7	.....
111	9.07 ± 3.5	011	101	110	−4.84 ± 5.3	21.48 ± 7.4	−3.55 ± 4.4
112	34.73 ± 5.3	012	102	110	16.74 ± 7.3	32.84 ± 7.1	22.11 ± 5.9
114	38.54 ± 5.1	014	104	110	10.92 ± 7.4	43.24 ± 6.4	25.92 ± 5.8
120	28.93 ± 3.9	020	100	...	18.91 ± 4.7	23.42 ± 6.3	.....
121	34.47 ± 4.7	021	101	120	15.72 ± 6.4	46.88 ± 6.8	5.54 ± 6.1
122	44.47 ± 8.1	022	102	120	25.95 ± 9.3	42.58 ± 9.4	15.54 ± 9.0
124	31.11 ± 5.3	024	104	120	9.75 ± 6.3	35.81 ± 6.6	2.18 ± 6.6
140	30.12 ± 6.1	040	100	...	10.67 ± 7.3	24.61 ± 7.9	.....
141	32.76 ± 6.3	041	101	140	−4.65 ± 7.9	45.17 ± 9.0	2.64 ± 8.8
142	40.11 ± 5.8	042	102	140	2.83 ± 7.3	38.22 ± 7.5	9.99 ± 8.4
144	55.58 ± 7.7	044	104	140	12.08 ± 10.1	60.28 ± 8.6	25.46 ± 9.8
200	−2.91 ± 2.2	...	...	...	−2.91 ± 2.2	.....	.....
201	−7.17 ± 1.8	001	...	200	1.81 ± 3.2	.....	−4.26 ± 2.8
202	−2.91 ± 4.8	002	...	200	−4.54 ± 5.0	.....	0
204	5.32 ± 5.9	004	...	200	1.74 ± 6.7	.....	8.23 ± 6.3
210	4.96 ± 5.5	010	200	...	−17.67 ± 7.3	7.87 ± 5.9	.....
211	14.45 ± 5.0	011	201	210	.54 ± 6.4	21.62 ± 5.3	9.49 ± 7.4
212	31.95 ± 6.3	012	202	210	13.96 ± 8.0	34.86 ± 7.9	26.99 ± 8.4
214	25.10 ± 5.2	014	204	210	−2.52 ± 7.5	19.78 ± 7.9	20.14 ± 7.6
220	31.50 ± 4.8	020	200	...	21.48 ± 5.5	34.41 ± 5.3	.....
221	31.92 ± 5.2	021	201	220	13.17 ± 6.7	39.09 ± 5.5	.42 ± 7.1
222	29.93 ± 5.2	022	202	220	11.41 ± 6.9	32.84 ± 7.1	−1.57 ± 7.1
224	16.50 ± 5.9	024	204	220	−4.86 ± 6.8	11.18 ± 8.3	−15.00 ± 7.6
240	29.16 ± 4.1	040	200	...	9.71 ± 5.7	32.07 ± 4.6	.....
241	26.20 ± 4.8	041	201	240	−11.21 ± 6.8	33.37 ± 5.1	−2.96 ± 6.3
242	25.66 ± 7.3	042	202	240	−11.62 ± 8.6	28.57 ± 8.7	−3.50 ± 8.4
244	27.27 ± 3.1	044	204	240	−16.23 ± 7.2	21.95 ± 6.7	−1.89 ± 5.1
400	−4.85 ± 2.6	...	...	...	−4.85 ± 2.6	.....	.....
401	17.38 ± 3.3	001	...	400	26.36 ± 4.3	.....	22.23 ± 4.2
402	−3.01 ± 4.3	002	...	400	−4.64 ± 4.6	.....	1.84 ± 5.0
404	−2.24 ± 3.7	004	...	400	−5.82 ± 4.9	.....	2.61 ± 4.5
410	14.81 ± 4.9	010	400	...	−7.82 ± 6.8	19.66 ± 5.5	.....
411	16.06 ± 5.1	011	401	410	2.15 ± 6.5	−1.32 ± 6.1	1.25 ± 7.1
412	12.14 ± 3.3	012	402	410	−5.85 ± 6.0	15.15 ± 5.4	−2.67 ± 5.9
414	30.12 ± 7.0	014	404	410	2.50 ± 8.8	32.36 ± 7.9	15.31 ± 8.5
420	38.98 ± 4.4	020	400	...	28.96 ± 5.2	43.83 ± 5.1	.....
421	22.35 ± 7.0	021	401	420	3.60 ± 8.2	4.97 ± 7.7	−16.63 ± 8.3
422	32.04 ± 3.2	022	402	420	13.52 ± 5.6	35.05 ± 5.4	−6.94 ± 5.4
424	35.53 ± 2.5	024	404	420	14.17 ± 4.2	37.77 ± 4.5	−3.45 ± 5.1
440	15.73 ± 4.0	040	400	...	−3.72 ± 5.6	20.58 ± 4.8	.....
441	24.94 ± 2.7	041	401	440	−12.47 ± 5.5	7.56 ± 4.3	9.21 ± 4.8
442	13.13 ± 3.1	042	402	440	−24.15 ± 5.5	16.14 ± 5.3	−2.60 ± 5.1
444	5.89 ± 3.1	044	404	440	−37.61 ± 7.2	8.13 ± 4.8	−9.84 ± 5.1

[a]The percentage increase obtained with each treatment is subtracted from the percentage increase obtained with the treatment listed in the column at the left to derive the efficiency factor of each element indicated.

[b]The "efficiency factor" of any one element in a given combination may be expressed as the difference between the effectiveness of the given combination and the effectiveness of a corresponding combination with the one element left out.